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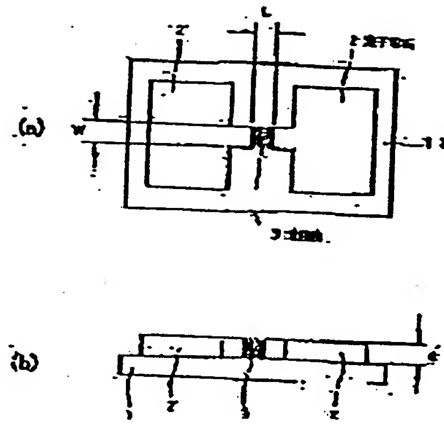
(54) ELECTRON EMISSION ELEMENT, ITS MANUFACTURE, AND ELECTRON SOURCE AND IMAGE FORMING DEVICE USING IT

(57)Abstract:



PURPOSE: To simplify fabrication processes and to provide a uniform electron emission characteristic by forming on an insulating substrate a pair of electrodes facing each other with a microclearance between them, and forming an electron emission element from a sediment accumulated in the clearance and composed chiefly of carbon.

CONSTITUTION: An element electrode material is accumulated on an insulating substrate 1 and then a predetermined cliarance L is formed between element electrodes 2, 2' by means of a convergent ion beam. A sediment 3 composed mainly of carbon is accumulated in the clearance L. The sediment 3 is preferably fibrous carbons, consisting of graphite or amorphous carbons. The fibrous carbons are produced by heat decomposition of hydrocarbons, such as benzene, or CO in a gaseous phase with the use of particles of Fe, etc., as catalysts. The use of Pd as the nuclei for formation of the fibrous carbons is desirable since the maximum process temperature can then be lowered to 450°C or less. Ni can also be used in addition to Fe and Pd.

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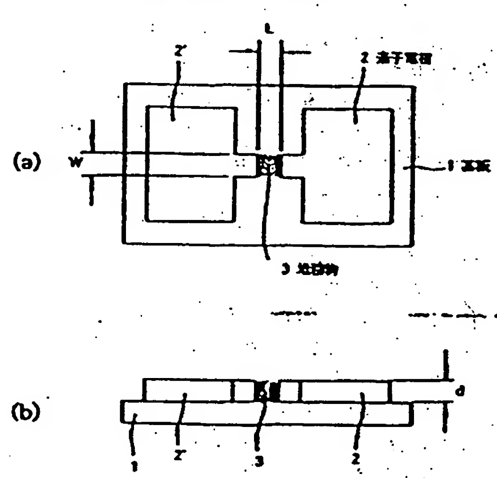
(54)【発明の名称】　電子放出素子及びその製造方法、該電子放出素子を用いた電子源並びに画像形成装置

(57)【要約】

【目的】　製造工程が繁雑でなく、均一な電子放出特性を有する電子放出素子を提供する。

【構成】　絶縁性基板1上に、素子電極2及び2′をつながった形状で形成し、収束イオンビームにより500nm以下の微小間隙Lを形成し、炭化水素ガスを含む雰囲気下で熱処理することにより炭素を主成分とする堆積物3を上記微小間隙に堆積させてなる電子放出素子。



は、エム アイ エリンソン，レィディオ エンジニアリング エレクトロン フィジクス，10（1965）（M. I. Elinson, Radio Eng. Electron Phys.）等がある。

【0006】

【発明が解決しようとする課題】上記に挙げたような電子放出素子を複数個用いて表示装置等を形成する場合、各素子の電子放出特性が均一であること、及び均一な素子の作製に繁雑な工程を伴わないことが要求される。従って、電子放出素子においては、こういった要求や更なる製造工程の簡略化、より優れた素子を達成するべく鋭意検討されている。

【0007】本発明の目的は、上記のような状況において、繁雑な工程を伴わずに均一な電子放出特性を示す信頼性の高い電子放出素子を提供することであり、更に、該電子放出素子を用いて電子源、更には画像形成装置を構成することにある。

【0008】

【課題を解決するための手段及び作用】請求項1～4の発明は、上記目的を達成した電子放出素子であって、絶縁性基板上に、微小間隙を介して一対の電極を設け、該微小間隙に炭素を主成分とする堆積物を有することに特徴を有する。

【0009】請求項5～14の発明は、上記電子放出素子の製造方法であって、絶縁性基板上に、微小間隙を設けて一対の電極を形成し、該微小間隙に炭素を主成分とする堆積物を堆積させることを特徴とする。

【0010】請求項15及び16の発明は上記電子放出素子を複数個配置したことを特徴とする電子源であり、請求項17及び18の発明はそれぞれの電子源を用いたことを特徴とする画像形成装置である。

【0011】以下本発明を詳細に説明する。

【0012】図1は本発明の電子放出素子の基本的な構成を示す図である。図中、1は絶縁性基板、2，2'は素子電極、3は炭素を主成分とする堆積物である。

【0013】基板1としては、例えば石英ガラス、Na等の不純物含有量を減少させたガラス、青板ガラス、青板ガラスにスパッタ法等によりSiO_2を積層した積層体、アルミナ等のセラミックス等が挙げられる。

【0014】対向する素子電極2，2'の材料としては、一般的導体材料が用いられ、例えばNi、Cr、Au、Mo、W、Pt、Ti、Al、Cu、Pd等の金属あるいは合金及びPd、Ag、Au、RuO_2、Pd－Ag等の金属あるいは金属酸化物とガラス等から構成される印刷導体、$In_2O_3-SnO_2$等の透明導電体及びポリシリコン等の半導体導体材料等から適宜選択される。

【0015】素子電極間隙L、素子電極長さWは、応用される形態等によって設計される。

【0016】素子電極長さWは、電極の抵抗値や電子放出特性を考慮すると、好ましくは数μm～数百μmであり、また素子電極厚dは、数百Å～数μmである。

【0017】素子電極間隙Lは、微小であり、好ましくは500nm以下である。

【0018】本発明の電子放出素子の製造方法について図2に基づいて説明する。尚、図2において図1と同じ符号は同じ部材を示すものである。

【0019】（A）基板1を洗剤、純水及び有機溶剤により十分に洗浄した後、真空蒸着法、スパッタ法等により素子電極材料を堆積させた後、フォトリソグラフィー技術により基板1の面上に素子電極2，2'がつながった状態を形成する（図2（a））。

【0020】（B）次に、収束イオンビーム（FIB）により、所定の間隙Lを素子電極2，2'間に形成する（図2（b））。間隙Lの形成は、上記FIBの他に、フォトリソグラフィーのプロセスを用いて形成する方法、或いは、基板1に段差を設けておいて間隙を形成する方法などが可能である。

【0021】（C）炭素を主成分とする堆積物を間隙Lに堆積する。本発明において、該堆積物は、好ましくは繊維状カーボンであり、グラファイト或いはアモルファスカーボンからなる。

【0022】繊維状カーボンは、ベンゼンなどの炭化水素やCOを気相で微粒子を触媒として熱分解した時に生成するもので、不規則な曲折を示したり、くびれを伴う場合もある（例えば、アール ティ ケイ ベーカー アンド ピィ エス ハリス：ケミストリィ アンド フィジクス オブ カーボン Vol. 14 p84～165，フィリップ エル ウォーカー ジュニア アンド ピーター エィスローワー編，マーセル ディーカー インク（R. T. K. Baker and P. S. Harris：Chemistry and Physics of Carbon, Philip L. Walker Jr. and Petere A. Thrower, MARCEL DEEKER, Inc.））。

【0023】Feなどの金属表面の、炭化水素ガスの分解反応における触媒活性は古くから研究されており、エチレンの分解についても多くの報告がある（例えば、矢ケ崎えり子・岩崎康裕「遷移金属表面におけるエチレンの化学」：表面 第29巻879～891頁 1991年）。

【0024】Feの微粒子がある場合には、炭化水素の存在する雰囲気中で熱処理することにより、微粒子を核にして繊維状カーボンが形成されることは上記の通り良く知られている。このFe微粒子はフェライト基板の一部などのFe化合物を還元して形成したものである。本発明者等は、電子放出素子の分野において広く用いられているPdからなる微粒子でも、Feと同様に繊維状カーボン形成時の核となることを見出した。従って本発明

子放出素子の製法及び測定時の測定条件等に依存する。但し、素子電流I_fが素子電圧V_fに対してVCNR特性を有する電子放出素子でも、放出電流I_eは素子電圧V_fに対してMI特性を有する。

【0042】次に、本発明の電子源における電子放出素子の配列について説明する。

【0043】本発明の電子源における電子放出素子の配列方式としては、並列に電子放出素子を配列し、個々の素子の両端（両素子電極）を配線（共通配線とも呼ぶ）にて夫々結線した行を複数行配列した梯型配置と、m本のX方向配線の上にn本のY方向配線を層間絶縁層を介して設置し、電子放出素子の一対の素子電極に夫々X方向配線、Y方向配線を接続した配置方式が挙げられる。これを以後単純マトリクス配置と呼ぶ。まず、この単純マトリクス配置について詳述する。

【0044】前述した電子放出素子の基本的特性によれば、単純マトリクス配置された電子放出素子における放出電子は、しきい値電圧を超える電圧では、対向する素子電極間に印加するパルス状電圧の波高値とパルス幅で制御できる。一方、しきい値電圧以下では殆ど電子は放出されない。従って、複数の電子放出素子を配置した場合においても、個々の素子に上記パルス状電圧を適宜印加すれば、入力信号に応じて電子放出素子を選択し、その電子放出量が制御でき、単純なマトリクス配線だけで個別の電子放出素子を選択して独立に駆動可能となる。

【0045】単純マトリクス配置はこのような原理に基づくもので、本発明の電子源の一例である、この単純マトリクス配置の電子源の構成について図5に基づいて更に説明する。

【0046】図5において基板1は既に説明したようなガラス板等であり、この基板1上に配列された電子放出素子54の個数及び形状は用途に応じて適宜設定されるものである。

【0047】m本のX方向配線52は、夫々外部端子D_{x1}, D_{x2}, ……, D_{xm}を有するもので、基板1上に、真空蒸着法、印刷法、スパッタ法等で形成した導電性金属等である。また、複数の電子放出素子54にほぼ均等に電圧が供給されるように、材料、膜厚、配線幅が設定されている。

【0048】n本のY方向配線53は、夫々外部端子D_{y1}, D_{y2}, ……, D_{yn}を有するもので、X方向配線52と同様に作成される。

【0049】これらm本のX方向配線52とn本のY方向配線53間には、不図示の層間絶縁層が設置され、電気的に分離されて、マトリクス配線を構成している。尚、このm, nは共に正の整数である。

【0050】不図示の層間絶縁層は、真空蒸着法、印刷法、スパッタ法等で形成されたSiO_2等であり、X方向配線52を形成した基板1の全面或は一部に所望の形状で形成され、特に、X方向配線52とY方向配線53の交差部の電位差に耐え得るように、膜厚、材料、製法が適宜設定される。

【0051】更に、電子放出素子54の対向する素子電極（不図示）が、m本のX方向配線52と、n本のY方向配線53と、真空蒸着法、印刷法、スパッタ法等で形成された導電性金属等からなる結線55によって電気的に接続されているものである。

【0052】ここで、m本のX方向配線52と、n本のY方向配線53と、結線55と、対向する素子電極とは、その構成元素の一部あるいは全部が同一であっても、また夫々異なっていてもよく、前述の素子電極の材料等より適宜選択される。これら素子電極への配線は、素子電極と材料が同一である場合は素子電極と総称する場合もある。また、電子放出素子54は、基板1或いは不図示の層間絶縁層上どちらに形成してもよい。

【0053】また、詳しくは後述するが、前記X方向配線52には、X方向に配列された電子放出素子54の行を入力信号に応じて走査するために、走査信号を印加する不図示の走査信号印加手段が電気的に接続されている。

【0054】一方、Y方向配線53には、Y方向に配列された電子放出素子54の列の各列を入力信号に応じて変調するために、変調信号を印加する不図示の変調信号発生手段が電気的に接続されている。更に、各電子放出素子54に印加される駆動電圧は、当該電子放出素子54に印加される走査信号と変調信号の差電圧として供給されるものである。

【0055】次に、以上のような単純マトリクス配置の本発明の電子源を用いた本発明の画像形成装置の一例を、図6～図8を用いて説明する。尚、図6は表示パネル81の基本構成図であり、図7は蛍光膜64を示す図であり、図8は図6の表示パネル81で、NTSC方式のテレビ信号に応じてテレビジョン表示を行うための駆動回路の一例を示すブロック図である。

【0056】図6において、1は上述のようにして電子放出素子を配置した電子源の基板、61は基板1を固定したリアプレート、66はガラス基板63の内面に蛍光膜64とメタルバック65等が形成されたフェースプレート、62は支持枠であり、リアプレート61、支持枠62及びフェースプレート66にフリットガラス等を塗布し、大気中あるいは窒素中で、400～500℃で10分以上焼成することで封着して外囲器68を構成している。

【0057】図6において、52、53は、電子放出素子54の一対の素子電極2、2'と接続されたX方向配線及びY方向配線で、夫々外部端子D_{x1}～D_{xm}, D_{y1}～D_{yn}を有している。

【0058】外囲器68は、上述の如く、フェースープレート66、支持枠62、リアプレート61で構成されている。しかし、リアプレート61は主に基板1の強度

から分離された画像の輝度信号成分を便宜上DATA信号と図示する。このDATA信号はシフトレジスタ８４に入力される。

【００７２】シフトレジスタ８４は、時系列的にシリアル入力される前記DATA信号を、画像の１ライン毎にシリアル／パラレル変換するためのもので、前記制御回路８３より送られる制御信号T_{sft}に基づいて作動する。この制御信号T_{sft}は、シフトレジスタ８４のシフトクロックであると言い換えてもよい。また、シリアル／パラレル変換された画像１ライン分（電子放出素子のｎ素子分の駆動データに相当する）のデータは、I_{d1}～I_{dn}のｎ個の並列信号として前記シフトレジスタ８４より出力される。

【００７３】ラインメモリ８５は、画像１ライン分のデータを必要時間だけ記憶するための記憶装置であり、制御回路８３より送られる制御信号T_{mry}に従って適宜I_{d1}～I_{dn}の内容を記憶する。記憶された内容は、I'_{d1}～I'_{dn}として出力され、変調信号発生器８７に入力される。

【００７４】変調信号発生器８７は、前記画像データI'_{d1}～I'_{dn}の各々に応じて、電子放出素子の各々を適切に駆動変調するための信号源で、その出力信号は、端子D_{y1}～D_{yn}を通じて表示パネル８１内の電子放出素子に印加される。

【００７５】前述したように、電子放出素子は電子放出に明確なしきい値電圧を有しており、しきい値電圧を超える電圧が印加された場合にのみ電子放出が生じる。また、しきい値電圧を超える電圧に対しては電子放出素子への印加電圧の変化に応じて放出電流も変化して行く。電子放出素子の材料、構成、製造方法を変えることにより、しきい値電圧の値や印加電圧に対する放出電流の変化度合いが変わる場合もあるが、いずれにしても以下のことがいえる。

【００７６】即ち、電子放出素子にパルス状の電圧を印加する場合、例えばしきい値電圧以下の電圧を印加しても電子放出は生じないが、しきい値電圧を超える電圧を印加する場合には電子放出を生じる。その際、第１には電圧パルスの波高値を変化させることにより、出力される電子ビームの強度を制御することが可能である。第２には、電圧パルスの幅を変化させることにより、出力される電子ビームの電荷の総量を制御することが可能である。

【００７７】従って、入力信号に応じて電子放出素子を変調する方式としては、電圧変調方式とパルス幅変調方式とが挙げられる。電圧変調方式を行う場合、変調信号発生器８７としては、一定の長さの電圧パルスを発生するが、入力されるデータに応じて適宜パルスの波高値を変調できる電圧変調方式の回路を用いる。また、パルス幅変調方式を行う場合、変調信号発生器８７としては、一定の波高値の電圧パルスを発生するが、入力されるデータに応じて適宜パルス幅を変調できるパルス幅変調方式の回路を用いる。

【００７８】シフトレジスタ８４やラインメモリ８５は、デジタル信号式のものでもアナログ信号式のものでもよく、画像信号のシリアル／パラレル変換や記憶が所定の速度で行えるものであればよい。

【００７９】デジタル信号式を用いる場合には、同期信号分離回路８６の出力信号DATAをデジタル信号化する必要がある。これは同期信号分離回路８６の出力部にA／D変換器を設けることで行える。

【００８０】また、これと関連して、ラインメモリ８５の出力信号がデジタル信号かアナログ信号かにより、変調信号発生器８７に設けられる回路が若干異なるものとなる。

【００８１】即ち、デジタル信号で電圧変調方式の場合、変調信号発生器８７には、例えばよく知られているD／A変換回路を用い、必要に応じて増幅回路等を付け加えればよい。また、デジタル信号でパルス幅変調方式の場合、変調信号発生器８７は、例えば高速の発振器及び発振器の出力する波数を計数する計数器（カウンタ）及び計数器の出力値と前記メモリの出力値を比較する比較器（コンパレータ）を組み合わせた回路を用いることで容易に構成することができる。更に、必要に応じて、比較器の出力するパルス幅変調された変調信号を電子放出素子の駆動電圧にまで電圧増幅するための増幅器を付け加えてもよい。

【００８２】一方、アナログ信号で電圧変調方式の場合、変調信号発生器８７には、例えばよく知られているオペアンプ等を用いた増幅回路を用いればよく、必要に応じてレベルシフト回路等を付け加えてもよい。また、アナログ信号でパルス幅変調方式の場合、例えばよく知られている電圧制御型発振回路（VCO）を用いればよく、必要に応じて電子放出素子の駆動電圧にまで電圧増幅するための増幅器を付け加えてもよい。

【００８３】以上のような表示パネル８１及び駆動回路を有する本発明の画像形成装置は、端子D_{x1}～D_{xm}及びD_{y1}～D_{yn}から電圧を印加することにより、必要な電子放出素子から電子を放出させることができ、高圧端子H_vを通じて、メタルバック５５あるいは透明電極（不図示）に高電圧を印加して電子ビームを加速し、加速した電子ビームを蛍光膜５４に衝突させることで生じる励起・発光によって、NTSC方式のテレビ信号に応じてテレビジョン表示を行うことができるものである。

【００８４】尚、以上説明した構成は、表示等に用いられる本発明の画像形成装置を得る上で必要な概略構成であり、例えば各部材の材料等、詳細な部分は上述の内容に限られるものではなく、画像形成装置の用途に適するよう、適宜選択されるものである。また、入力信号としてNTSC方式を挙げたが、本発明に係る画像形成装置はこれに限られるものではなく、PAL、SECAM方

いる様子が観察された。但し、間隙中央部ではやや疎になっていた。

【0104】［実施例3］実施例1と同様にして素子電極、及び該電極間の間隙を形成し、有機Pd錯体溶液を塗布、300℃で焼成を行なった後、窒素で希釈した0．1％エチレン気流中で180℃で10分間の熱処理を行ない、引き続き450℃に昇温して10分間の熱処理を行なった。この電子放出素子の電気的特性は実施例1とほぼ同様であった。

【0105】［比較例1］実施例1と同様の工程で素子電極及び電極間隙を形成し、Pd微粒子を形成した後、エチレン雰囲気中での熱処理工程を省いて、I_e及びI_fを測定した。その結果、I_e、I_f共に観測されなかった。

【0106】［比較例2］電極間隙を900nmとする以外は実施例1と同様にして電子放出素子を作製し、I_e及びI_fを測定したところ、I_e、I_fとも全く観測されなかった。

【0107】この電子放出素子を走査電子顕微鏡で観察したところ、素子電極の端面付近には繊維状カーボンが形成されているが、間隙の中央部には存在せず、両方のカーボン間の間隔が大きく開いていることがわかった。これは、有機Pd溶液を塗布した際、表面張力により電極端面付近に溶液が集まり、中央付近は少なくなるために、Pd微粒子が間隙中央部に形成されず、従って、これを核として堆積する繊維状カーボンが堆積しにくかったものと推測される。そのため、カーボン間の間隙が広く、I_e、I_fが観測されなかった、即ち素子電極間に電流が流れず電子放出が行なわれなかったものと推測される。

【0108】［実施例4］単純マトリクス配線により電子放出素子を配置した電子源を作製した。その手順を以下に示す。

【0109】洗浄した青板ガラスの基板上に真空蒸着法により厚さ5nmのCr、厚さ60nmのAuを順次積層した後、フォトレジスト（AZ1370：ヘキスト社製）をスピンナーにより回転塗布、ベークした後、フォトマスク像を露光、現像して、下配線のレジストパターンを形成し、Au／Cr積層膜をウエットエッチングして下配線を形成した。

【0110】厚さ0．1μmのシリコン酸化膜からなる層間絶縁層を高周波スパッタ法により形成した。

【0111】堆積したシリコン酸化膜上にコンタクトホールを形成するためのフォトレジストパターンを作り、これをマスクとして層間絶縁層をエッチングしてコンタクトホールを形成した。エッチングはCF_4とH_2ガスを用いたRIE（Reactive Ion Etching）法によった。

【0112】素子電極となるべきパターンをフォトレジスト（RD－2000N－41：日立化成社製）で形成し、真空蒸着法により厚さ5nmのTi、厚さ100nmのNiを順次積層した。フォトレジストパターンを有機溶剤で溶解し、Ni／Ti堆積膜をリフトオフし素子電極を形成した。

【0113】素子電極の上に上配線のフォトレジストパターンを形成した後、厚さ5nmのTi、厚さ100nmのAuを順次真空蒸着法により堆積し、リフトオフにより不要の部分を除去して上配線を形成する。

【0114】コンタクトホール部分以外をカバーするようにレジスト膜を形成し、真空蒸着法により厚さ5nmのTi、厚さ500nmのAuを順次積層した。リフトオフにより不要部分を除去することにより、コンタクトホールを埋め込んだ。

【0115】実施例1と同様に、FIBにより素子電極間に間隙を形成した。更に、実施例1と同様にして、有機Pd錯体溶液をスピンナーで塗布し、大気中300℃で焼成してPdOとし、更にN_2－2％H_2混合ガス気流中で180℃10分間の熱処理を行ないPd微粒子を形成した。

【0116】実施例1と同様に、0．01％C_2H_4気流中で500℃10分間の熱処理を行ない、繊維状カーボンを形成した。高分解能SEM（走査型電子顕微鏡）によりこの電子源の電子放出素子を観察したところ、熱処理により、素子電極上のPd微粒子は電極中に拡散したらしく、素子電極上には微粒子も繊維状カーボンも見られなかった。

【0117】この電子源に図11に示すように引き出し電極と蛍光板を取り付け、全ての電子放出素子を時間順次に走査駆動した。図11の系を説明する。図中111は真空槽であり、不図示の排気系により、5×10^{-5}Pa以下に排気されている。112は窓、114は電子放出部（電極間隙）、電極、配線などからなる素子本体である。115、116はX方向及びY方向ラインの駆動用配線である。117は前記配線に適当なパルスを印加するドライバーである。118は引き出し電極で、アルミニウム製の枠に透明電極のITO薄膜を形成したガラスを嵌め込み、その下面に蛍光体を塗布したものである。

【0118】電子放出素子に、駆動電圧14V、半選択電圧7Vとなるようにドライバー117で矩形波パルスを印加した。引き出し電圧は5kVである。

【0119】窓112を通して、電子放出による蛍光体の発光を目視で観察したところ、本実施例の電子源においては、素子間での輝度のばらつきが小さく、電子放出特性の均一性が高いことが確認された。

【0120】［実施例5］実施例4の電子源に、図6に示すように画像形成部材を組み合わせ、例えばテレビジョン放送をはじめとする種々の画像情報源より提供される画像情報を表示できる表示装置を構成した。図12にそのブロック図を示す。

するためのものであり、例えばキーボードやマウスの他、ジョイスティック、バーコードリーダー、音声認識装置など多様な入力機器を用いることが可能である。

【0138】また、デコーダ124は、前記127ないし133より入力される種々の画像信号を3原色信号、または輝度信号とI信号、Q信号に逆変換するための回路である。尚、同図中に点線で示すように、デコーダ124は内部に画像メモリを備えるのが望ましい。これは、例えばMUSE方式をはじめとして、逆変換するに際して画像メモリを必要とするようなテレビ信号を扱うためである。また、画像メモリを備えることにより、静止画の表示が容易になる。或いは前記画像生成回路127及びCPU126と協同して画像の間引き、補間、拡大、縮小、合成をはじめとする画像処理や編集が容易に行なえるようになるという利点が生まれるからである。

【0139】また、マルチプレクサ123は前記CPU126より入力される制御信号に基づき表示画像を適宜選択するものである。即ち、マルチプレクサ123はデコーダ124から入力される逆変換された画像信号のうちから所望の画像信号を選択して駆動回路121に出力する。その場合には、一画面表示時間内で画像信号を切り換えて選択することにより、いわゆる多画面テレビのように、一画面を複数の領域に分けて領域によって異なる画像を表示することも可能である。

【0140】また、ディスプレイパネルコントローラ122は、前記CPU126より入力される制御信号に基づき駆動回路121の動作を制御するための回路である。

【0141】先ず、ディスプレイパネルの基本的な動作に関わるものとして、例えばディスプレイパネルの駆動用電源（不図示）の動作シーケンスを制御するための信号を駆動回路121に対して出力する。

【0142】また、ディスプレイパネルの駆動方法に関わるものとして、例えば画面表示周波数や走査方法（例えばインターレースかノンインターレースか）を制御するための信号を駆動回路121に対して出力する。

【0143】また、場合によっては表示画像の輝度、コントラスト、色調、シャープネスといった画質の調整に関わる制御信号を駆動回路121に対して出力する場合もある。

【0144】また、駆動回路121は、ディスプレイパネル120に印加する駆動信号を発生するための回路であり、前記マルチプレクサ123から入力される画像信号と、前記ディスプレイパネルコントローラ122より入力される制御信号に基づいて動作するものである。

【0145】以上、各部の機能を説明したが、図12に例示した構成により、本表示装置においては多様な画像情報源より入力される画像情報をディスプレイパネル120に表示することが可能である。即ち、テレビジョン放送をはじめとする各種の画像信号はデコーダ124において逆変換された後、マルチプレクサ123において適宜選択され、駆動回路121に入力される。一方、ディスプレイコントローラ122は、表示する画像信号に応じて駆動回路121の動作を制御するための制御信号を発生する。駆動回路121は、上記画像信号と制御信号に基づいてディスプレイパネル120に駆動信号を印加する。これにより、ディスプレイパネル120において画像が表示される。これらの一連の動作は、CPU126により統括的に制御される。

【0146】また、本表示装置においては、前記デコーダ124に内蔵する画像メモリや、画像生成回路127及びCPU126が関与することにより、単に複数の画像情報の中から選択したものを表示するだけでなく、表示する画像情報に対して、例えば拡大、縮小、回転、移動、エッジ強調、間引き、補間、色変換、画像の縦横比変換などをはじめとする画像処理や、合成、消去、接続、入れ替え、はめ込みなどをはじめとする画像編集を行なうことも可能である。また、本実施例の説明では、特に触れなかったが、上記画像処理や画像編集と同様に、音声情報に関しても処理や編集を行なうための専用回路を設けても良い。

【0147】従って、本表示装置は、テレビジョン放送の表示機器、テレビ会議の端末機器、静止画像及び動画像を扱う画像編集機器、コンピューターの端末機器、ワードプロセッサをはじめとする事務用端末機器、ゲーム機などの機能を一台で兼ね備えることが可能で、産業用或いは民生用として極めて応用範囲が広い。

【0148】尚、上記図12は、電子放出素子を電子源とするディスプレイパネルを用いた表示装置の構成の一例を示したに過ぎず、これのみに限定されるものでないことは言うまでもない。例えば図12の構成要素のうち使用目的上必要のない機能に関わる回路は省いても差し支えない。またこれとは逆に、使用目的によってはさらに構成要素を追加しても良い。例えば、本表示装置をテレビ電話機として応用する場合には、テレビカメラ、音声マイク、照明機、モデムを含む送受信回路などを構成要素に追加するのが好適である。

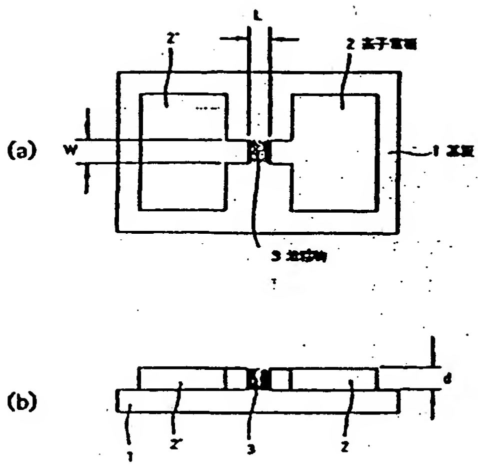
【0149】本表示装置においては、とりわけ電子放出素子を電子源とするディスプレイパネルの薄型化が容易なため、表示装置の奥行きを小さくすることができる。それに加えて、電子放出素子を電子源とするディスプレイパネルは大画面化が容易で輝度が高く視野角特性にも優れるため、本表示装置は臨場感あふれ迫力に富んだ画像を視認性良く表示することが可能である。

【0150】更に、本発明の電子源は各電子放出素子間での電子放出特性が均一であるため、形成される画像の画質が高く、また高精細な画像の表示も可能である。

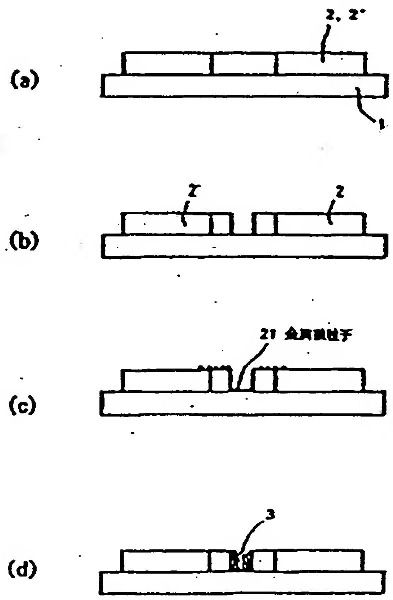
【0151】

【発明の効果】以上説明したように、本発明によれば、良好な電子放出特性を示す電子放出素子を信頼性高く提

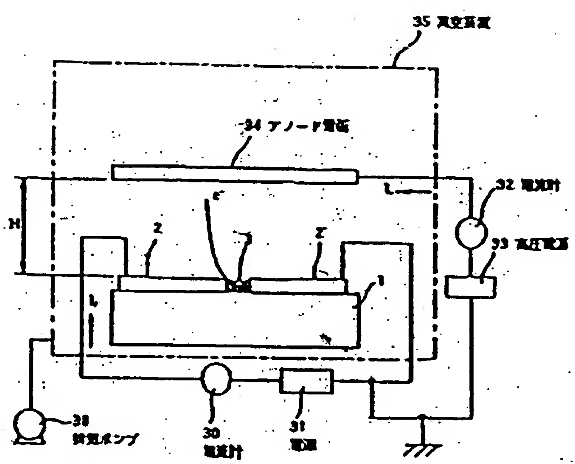
【図1】


L
2'
2 素子電極
(a)
W
1 基板
(b)
d
1
2'
3
2

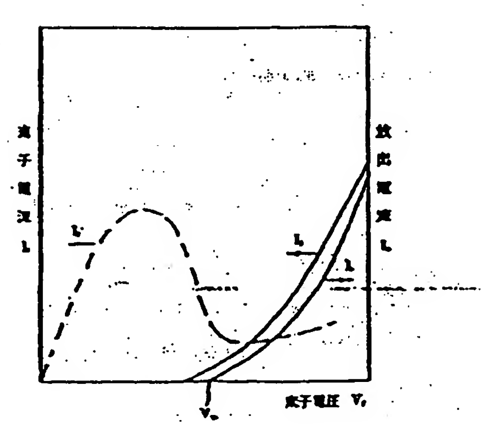
【図2】


2, 2'
(a)
1
2'
2
(b)
21 金属微粒子
(c)
3
(d)

【図3】


35 真空装置
34 アノード電極
32 電流計
H
2
2'
33 高圧電源
1
38
排気ポンプ
30
電流計
31
電源

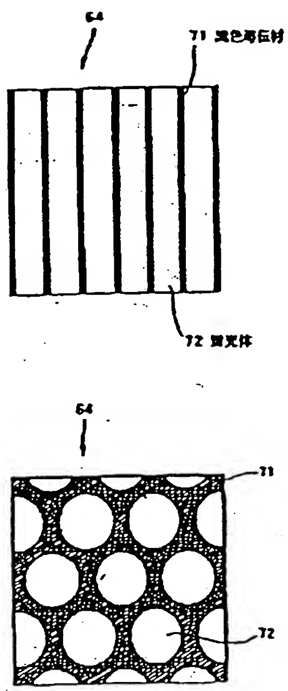
【図4】


素子電流 If
放出電流 Ie
素子電圧 Vf

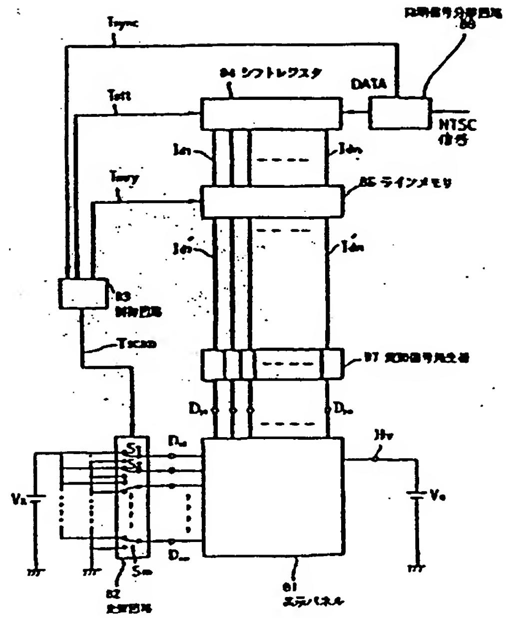
【図7】

(a)

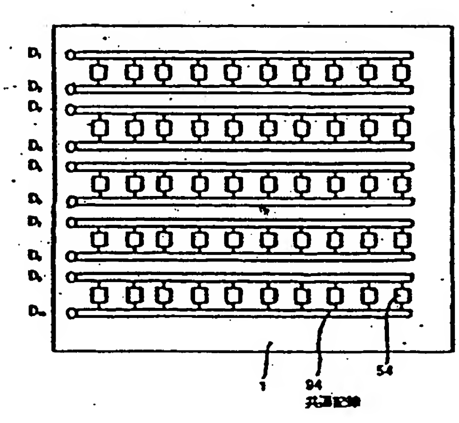
(b)


64
71 黒色導伝材
72 蛍光体
71
72

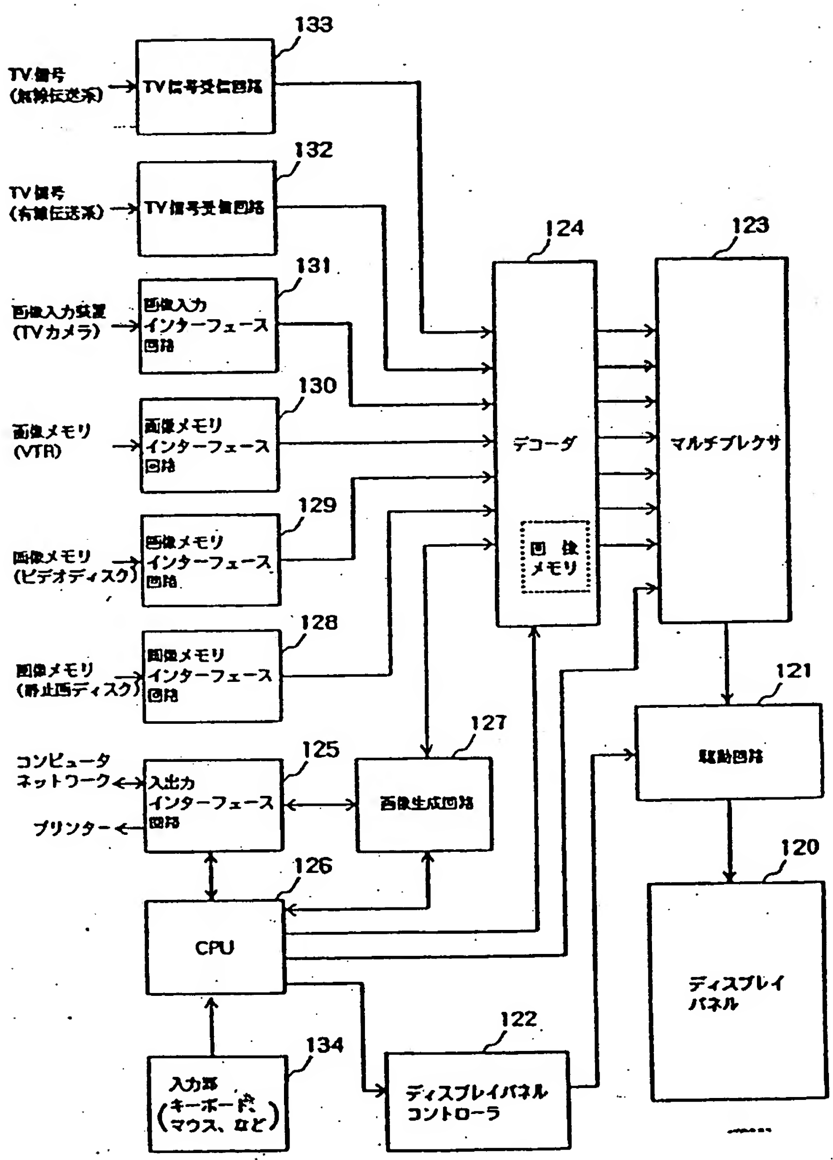
【図8】


Tsync
84 シフトレジスタ
DATA
NTSC
信号
Tsft
85 ラインメモリ
Tmry
83
制御回路
Tscan
DATA
NTSC
Vx
Vo
Hv
81
表示パネル

【図9】


1
94
共通配線
54

【図12】


133
TV信号
(無線伝送系)
TV信号受信回路
132
TV信号
(有線伝送系)
TV信号受信回路
131
画像入力装置
(TVカメラ)
画像入力
インターフェース
回路
130
画像メモリ
(VTR)
画像メモリ
インターフェース
回路
129
画像メモリ
(ビデオディスク)
画像メモリ
インターフェース
回路
128
画像メモリ
(静止画ディスク)
画像メモリ
インターフェース
回路
125
コンピュータ
ネットワーク
プリンター
入出力
インターフェース
回路
127
画像生成回路
126
CPU
134
入力部
(キーボード、マウス、など)
122
ディスプレイパネル
コントローラ
124
デコーダ
画像
メモリ
123
マルチプレクサ
121
駆動回路
120
ディスプレイ
パネル

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(54) [Title of the Invention] Electron Emission Device, Method of Manufacturing the Same, and Electron Source and Image Forming Apparatus using Electron Emission Device

(57) [Abstract]

[Object] To provide an electron emission device having a uniform electron emission characteristic, which is manufactured by simple manufacturing processes.

[Constitution] An electron emission device formed in such a manner that device electrodes 2 and 2' are formed on an insulating substrate 1 to a shape in which the electrodes 2 and 2' are connected to each other, minute intervals L of 500 nm or less are formed by focused ion beam, and a deposit 3 essentially containing carbon is formed in the minute interval by thermal treatment at atmosphere containing hydrocarbon gas.

[What is claimed is]

[Claim 1] An electron emission device characterized by at least comprising an insulating substrate; a pair of electrodes formed on the insulating substrate, the pair of electrodes facing to each other so as to interpose a minute gap therebetween; and a deposit deposited in the minute gap, the deposit essentially containing carbon.

[Claim 2] The electron emission device according to claim 1, wherein the minute gap is 500 nm or less.

[Claim 3] The electron emission device according to claim 1 or 2, wherein the deposit essentially containing carbon is an aggregate formed of a fibrous material.

[Claim 4] The electron emission device according to claim 3, wherein the fibrous carbon is formed of graphite, amorphous carbon or mixture of graphite and amorphous carbon.

[Claim 5] A method of manufacturing an electron emission device is characterized by comprising a step of forming a pair of electrodes on an insulating substrate, the pair of electrodes facing to each other so as to interpose a minute gap therebetween; and a step of depositing a deposit in the minute gap, the deposit essentially containing carbon.

[Claim 6] The method of manufacturing an electron emission device according to claim 5, the depositing step of the deposit essentially containing carbon is a thermal decomposition step of carbon compound.

[Claim 7] The method of manufacturing an electron emission device according to claim 6, wherein the carbon compound is hydro carbon.
[Claim 8] The method of manufacturing an element emission device according to claim 7, wherein the hydrocarbon is ethylene.
[Claim 9] The method of manufacturing an element emission device according to any one of claims 6 to 8, wherein the decomposition step of the carbon compound is a heating step at atmosphere containing the carbon compound.
[Claim 10] The method of manufacturing an electron emission device according to any one of claims 5 to 9, the deposition step of the deposit essentially containing the carbon comprises a step of forming metal fine particles in the inter-electrode minute gap; and a step of depositing fibrous carbon by use of the metal fine particles as a nucleus by thermally decomposing the carbon compound.

[Claim 11] The method of manufacturing an electron emission device according to claim 10, wherein the step of forming the metal fine particles comprises a step of coating organic complex solution of the metal onto the inter-electrode gap; a step of baking the organic metal complex to convert the organic metal complex to metal oxide; and a step of reducing the metal oxide and aggregating the metal oxide.

[Claim 12] The method of manufacturing an electron emission device according to claim 11, wherein the step of reducing and aggregating the metal oxide is a step of exposing the metal oxide at atmosphere containing hydrogen gas or a step of thermally heating the metal oxide at this atmosphere.
[Claim 13] The method of manufacturing an electron emission device according to any one of claims 10 to 12, wherein the deposition step of the fibrous carbon is a step of performing a thermal treatment at a thermal decomposition temperature or more of ethylene at atmosphere containing the ethylene.
[Claim 14] The method of manufacturing an electron emission device according to any one of claims 10 to 12, wherein the step of reducing and aggregating the metal oxide is performed by thermally treatment for the metal oxide at a thermal decomposition temperature or less of ethylene at atmosphere containing ethylene gas, and subsequently heating the metal oxide to the thermal decomposition temperature or more of ethylene at the same atmosphere, thus performing the deposition step of the fibrous carbon.
[Claim 15] An electron source is characterized by comprising at least one device

array which is constituted by arranging the plurality of electron emission devices claimed in any one of claims 1 to 4 in parallel and coupling the plurality of electron emission devices to each other.

[Claim 16] An electron source is characterized by comprising at least one device array which is constituted by arranging the plurality of electron emission devices claimed in any one of claims 1 to 4, wherein wirings for driving the devices are matrix-arrayed.

[Claim 17] An image formation apparatus is characterized by comprising the electron source claimed in claim 15, an image formation member, and a control electrode for controlling an electron beam emitted from each electron emission device by an information signal.

[Claim 18] An image formation apparatus is characterized by comprising the electron source claimed in claim 16 and an image formation member.

[Detailed Description of the Invention]

[0001]

[Field of Industrial Application] The present invention relates to an electron emission device, an electron source constituted by arranging the plurality of electron emission devices, and an image formation apparatus such as a display device and an exposure apparatus, which are constituted by use of the electron source, and furthermore, to a method of manufacturing the foregoing electron emission device.

[0002]

[Prior Art] Two kinds of thermoelectron source and cold cathode electron source have been heretofore known as an electron emission device, and there have been a field emission type (hereinafter referred to as a FE type) cold cathode electron source, a metal/insulating layer/metal type (hereinafter referred to as a MIM type) cold cathode electron source and a surface conduction type cold cathode electron source.

[0003] As an example of the FE type, "Field emission", Advance in electron Physics, 8, 89 (1956) by W. P. Dyke & W. W. Dolan, and "PHYSICAL Properties of thin-film field emission cathodes with molybdenium cones" J. Appl. Phys. 47, 5248 (1976) by C. A. Spindt and the like have been known.

[0004] Furthermore, as an example of MIM type, "The tunnel-emission amplifier", J. Appl. Phys., 32, 646(1961) by C. A. Mead and the like has been known.

[0005] Furthermore, as an example of the surface conduction type electron emission device, the one has been described in Radio Eng. 10 (1965) Electron Phys. by M. I. Elinson.

[0006]

[Subjects to be Solved by the Invention] When the display device and the like are constructed by use of the plurality of electron emission devices as described above, uniformity of electron emission characteristics of the devices is required, and uncomplicated processes for the fabrication of the devices showing the uniform electron emission property is required. Accordingly, as to the electron emission device, eager examinations have been conducted to meet such a demand, and to achieve further simplification of the manufacturing steps and more excellent device.

[0007] An object of the present invention is to provide an electron emission device with high reliability, which shows a uniform electron emission property without accompanying complicated processes, and further another object of the present invention is to constitute an electron source by use of the electron emission device, and an image formation apparatus.

[0008]

[Means for Solving the Subjects and Operation] The invention defined in claims 1 to 4 is an electron emission device which achieves the above described object, and characterized in that a pair of electrodes are provided on an insulating substrate so as to interpose a minute gap therebetween; and a deposit is provided in the minute gap, the deposit essentially containing carbon.

[0009] The invention defined in claims 5 to 14 is a manufacturing method of the foregoing electron emission device, and is characterized in that a pair of electrodes is provided on an insulating substrate so as to interpose a minute gap therebetween; and a deposit is provided in the minute gap, the deposit essentially containing carbon.

[0010] The invention defined in claims 15 and 16 is an electron source characterized in that the plurality of electron emission devices are arranged, and the invention defined in claim 17 and 18 is an image formation apparatus characterized by using the respective electron sources.

[0011] The present invention will be described in detail below.

[0012] Fig. 1 is a drawing showing a basic constitution of an electron emission device of the present invention. In the drawing, reference numeral 1 denotes

an insulating substrate; 2 and 2', a device electrode; and 3, a deposit essentially containing carbon.

[0013] As the substrate 1, enumerated are, for example, quartz glass, glass in which the content of impurities such as Na is reduced, soda lime glass, a stacked body in which SiO_2 is stacked on the soda lime glass by a sputtering method or like, ceramics such as alumina and the like.

[0014] As a material of the device electrodes 2 and 2' facing to each other, a general conductive material is used. A printing conductor composed of a metal including, for example, Ni, Cr, Au, Mo, W, Pt, Ti, Al, Cu, Pd and the like or alloy of these metals, a metal including Pd, Ag, Au, RuO_2, Pd-Ag and the like or metal oxide of these metals, glass and the like, a transparent conductor such as In_2O_3-SnO_2 and a semiconductor material such as polysilicon are properly selected.

[0015] The device electrode gap L and the device electrode length W are designed according to a type applied and the like.

[0016] The device electrode length W should preferably be several μm to several hundred μm in consideration of the resistivity of the electrode and the electron emission characteristic. The thickness d of the device electrode should preferably be several hundred Å to several μm.

[0017] The gap L between the device electrodes should be minute, and should preferably be equal to 500 nm or less.

[0018] Descriptions for a method of manufacturing an electron emission device of the present invention will be made based on Fig. 2. Note that in Fig. 2, the same reference numerals as those in Fig. 1 shows the same member.

[0019] (A) After the substrate 1 is fully washed out by a cleaning material, pure water and organic solvent, a device electrode material is deposited thereon by a vacuum deposition method, a sputtering method or the like. Afterward, a state where the device electrodes 2 and 2' are communicated with each other is formed on the plane of the substrate 1 by use of a photolithography technique (Fig. 2(a)).

[0020] (B) Next, a predetermined gap L is formed between the device electrodes 2 and 2' by use of a focused ion beam (FIB) (Fig. 2(b)). The gap L can be formed by a method by use of processes of photolithograpy or by a method in which a step difference is previously provided in the substrate 1, in addition to the foregoing FIB.

[0021] (C) A deposit essentially containing carbon is deposited in the gap L. In the present invention, the deposit should preferably be fibrous carbon, which is formed of graphite or amorphous carbon.

[0022] The fibrous carbon is generated when hydrocarbon such as benzene and CO are thermally decomposed at a vapor phase by use of fine particles as catalyst, and the fibrous carbon shows irregular bending, and may accompany constrictions (for example, R. T. K. Baker and P. S. Harris: Chemistry and Physics of Carbon, Vol. 14 p84 to 165 by Philip L. Walker Jr. and Petere A. Thrower, MARCEL DEEKER, inc.).

[0023] Catalyst activity in the decomposition reaction of hydrocarbon gas on the surface of a metal such as Fe has been investigated from a long time ago, and there have been many reports as to the decomposition of ethylene (for example, "Chemistry of ethylene on surface of transition metal" by Eriko Yagazaki & Yasuhiro Iwasaki, Surface, Vol. 29, pp 879 to 891, 1991).

[0024] In the case where fine particles of Fe exist, the fact that the fibrous carbon is formed around the nucleus of the fine particles by performing the thermal treatment at the atmosphere in which the hydrocarbon exist has been well known as described above. The Fe fine particles are formed by reducing a Fe compound forming a part of a ferrite substrate. The inventors of the present invention found that fine particles formed of Pd widely used in a field of the electron emission device serve also as the nucleus in forming the fibrous carbon similarly to Fe. Accordingly, in the present invention, when Pd is used as the nucleus for forming the fibrous carbon, it is possible to control the process maximum temperature to 450 ℃ or less (when Fe is used, the process maximum temperature ranges from 950 to 1000 ℃). Therefore, Pd is preferable in terms of influences on other members and manufacturing cost.

[0025] To be concrete, after organic metal complex solution using Pd and the like is coated and thermally baked, thus converting the solution to a metal oxide, the metal oxide is exposed to atmosphere containing hydrogen gas or subjected to a thermal treatment at this atmosphere, and hence the metal oxide is reduced and aggregated. Thus, metal fine particles 21 are produced (Fig. 2(c)).

[0026] In the present invention, as the nucleus for forming the fibrous carbon, Ni is preferably used in addition to the foregoing Fe and Pd, The nucleus needs not to assume a shape of fine particles. The same effects can be obtained if it is forms, such as a projection shape, which is a singular point of a growth of

the fibrous carbon.

[0027] The fibrous carbon is deposited by using the foregoing metal fine particles as the nucleus (Fig. 2(d)). The deposition method in which carbon compound such as hydrocarbon is thermally decomposed as described above at atmosphere containing ethylene gas may be employed. For example, the carbon compound may be subjected to the thermal treatment at atmosphere containing ethylene gas at a temperature higher than the thermal decomposition of ethylene. In addition to ethylene, hydrocarbon gas such as methane, propane and propylene and vapor of organic solvent such as methanol and acetone can be used.

[0028] The inventors of the present invention confirmed that the fibrous carbon is not formed at a temperature of 400 ℃ or less. On the other hand, at a temperature higher than 400 ℃, it is possible to form the fibrous carbon over a fully wide range. The fibrous carbon similar to that of an embodiment to be described later is formed by a thermal treatment at 900 ℃. However, as described above, since other members of the device are affected by the thermal treatment at the high temperature, a thermal treatment carried out at a temperature lower than 900 ℃ or less is preferable. Actually, the temperature of the thermal treatment should be set based on a heat-resistant temperature of the electrode and the substrate.

[0029] Moreover, the reduction step of the foregoing metal fine particles is, for example, performed at a temprature lower than the thermal decomposition temperature of ethylene at atmosphere containing ethylene gas, and subsequently a thermal treatment at the thermal decomposition temperature or more of ethylene is performed, whereby the reduction step of the metal fine particles and the deposition step of the fibrous carbon can be conducted continuously, and this is preferable in terms of simplification of the manufacturing steps.

[0030] When a sample was observed by a scanning electron microscope, which was obtained by thermally treating a Pd particle-dispersed film at ethylene atmosphere, in which Pd fine particles were formed, by the similar step as that of an embodiment to be described later, on a silicon substrate having a surface on which a thermal oxide film was formed, the fibrous carbon was observed. It was confirmed by an X-ray photoelectron spectrometry (XPS) and a RAMAN spectrometry that this was carbon. Moreover, when the fibrous carbon was

observed by a transmission electron microscope, a lattice image was observed, and the fibrous carbon possesses crystallinity. Note that the lattice image is very distorted, and the crystallinity is poor.

[0031] Fig. 3 is a schematic constitution view showing an example of a measurement evaluation system for measuring an electron emission characteristic of the electron emission device, and descriptions of the measurement evaluation system will be made.

[0032] In Fig. 3, the same reference numerals as those of Fig. 1 denote the same members. Reference numeral 31 denotes a power source for applying a device voltage V_f to the device; 30, a current meter for measuring a device current I_f flowing between the device electrodes 2 and 2'; 34, an anode electrode for capturing an emission current I_e; 33, a high voltage power source for applying a voltage to the anode electrode 34; 32, a current meter for measuring the emission current I_e; 35, a vacuum apparatus; and 36, an air exhaustion pump.

[0033] The electron emission device, the anode electrode 34 and the like are installed in the vacuum apparatus 35. In this vacuum apparatus 35, necessary instruments such as a vacuum meter (not shown) are provided, so that measurement evaluations of the electron emission device can be performed under a desired vacuum.

[0034] The air exhaustion pump 36 is constituted by an ordinary high vacuum apparatus system composed of a turbo pump, a rotary pump and the like, and a ultra high vacuum apparatus system composed of an ion pump and the like. Moreover, the measurement evaluation system is designed so that the whole of the vacuum apparatus 35 and the substrate 1 of the electron emission device can be heated to about 200 ℃ by a heater.

[0035] The basic characteristic of the electron emission device, which is to be described below, is based on measurement conducted in such a manner that a voltage of the anode electrode 34 of the foregoing measurement evaluation system is set to 1 kV to 10 kV, and the distance H between the anode electrode 34 and the electron emission device is set to 2 to 8 mm.

[0036] First, a typical example of a relation of the emission current I_e and the device current I_f with the device voltage V_f is shown in Fig. 4. Note that in Fig. 4, since the emission current I_e is significantly smaller than the device current I_f, both are represented by an arbitrary unit.

[0037] As is clear from Fig. 4, the electron emission device of the present

invention has the following three pathognomonic characteristics for the emission current I_e.

[0038] First of all, when the device voltage V_f equal to a certain voltage (referred to as a threshold voltage: V_{th} in Fig. 5) or more is applied to the electron emission device, the emission current I_e rapidly increases. On the other hand, when a voltage less than the threshold voltage V_{th} is applied thereto, the emission current I_e is not almost detected. Specifically, this electron emission device is a non-linear device having a clear threshold voltage V_{th} for the emission current I_e.

[0039] Secondly, since the electron emission device has a characteristic (referred to as a MI characteristic) that the emission current I_e increases monotonously relative to the device voltage V_f, the emission current I_e can be controlled by the device voltage V_f.

[0040] Thirdly, the emission charges captured at the anode electrode 34 (see Fig. 3) depend on a time for which the device voltage V_f is applied. Specifically, the charge amount captured by the anode electrode 34 can be controlled by a time for which the device voltage V_f is applied.

[0041] The emission current I_e has the MI characteristic relative to the device voltage V_f and, at the same time, also the device current I_f sometimes has the MI characteristic relative to the device voltage V_f. An example of such a characteristic of the electron emission device is the characteristic indicated by the solid lines in Fig. 4. On the other hand, as shown by the dotted line in Fig. 4, the device current I_f may show a voltage control type negative resistance characteristic (referred to as a VCNR characteristic) relative to the device voltage V_f. Which characteristic the electron emission device shows depends on a manufacturing method of the electron emission device, measurement conditions and the like. However, in the electron emission device in which the device current I_f shows the VCNR characteristic relative to the device voltage V_f, the emission current I_e has the MI characteristic relative to the device voltage V_f.

[0042] Next, the arrangement of the electron emission devices in the electron source of the present invention will be described.

[0043] As the arrangement style of the electron emission devices in the electron source of the present invention, enumerated are a ladder type array in which the electron emission device are arrayed in parallel, and a plurality of columns

are arrayed, each column being composed of the plurality of electron emission devices, both terminals (both device electrodes) of which are respectively coupled by a wiring (referred also to as a common wiring), and an array style in which n-pieces Y-direction wirings are placed on m-pieces X-direction wirings so as to interpose an interlayer insulating layer therebetween, and the X-direction wirings and the Y-direction wirings are respectively coupled to a pair of device electrodes of the electron emission device. This is hereinafter referred to as a simple matrix array style. First, descriptions of this simple matrix array will be made in detail.

[0044] According to the basic characteristic of the foregoing electron emission device, the emission electrons in the electron emission device, each of which is arrayed with the simple matrix array style, can be controlled, in a voltage range exceeding the threshold voltage, by a peak value of a pulse-like voltage and a pulse width thereof, which is applied between the device electrodes facing each other. On the other hand, below the threshold voltage, electrons are not almost emitted. Accordingly, even in the case where the plurality of electron emission devices are arrayed, if the foregoing pulse-like voltage is appropriately applied to the respective device, an electron emission device is selected in accordance with an input signal, and the selected electron emission device can be controlled. Thus, the individual electron emission device is selected to be independently driven only with the simple matrix wiring.

[0045] The simple matrix array is based on such a principle, and an example of the electron source of the present invention. The constitution of the electron source with this simple matrix array will be further described based on Fig. 5.

[0046] In Fig. 5, the substrate 1 is made of the glass plate and the like as described above, and the number and shape of the electron emission devices 54 arrayed on the substrate 1 are suitably set according to the use.

[0047] The m-pieces X-direction wirings 52 have external terminals D_{x1}, D_{x2}, ..., and D_{xm}, respectively, and are made of a conductive metals or the like formed by use of a vacuum deposition method, a printing method, a sputtering method or the like on the substrate 1. Moreover, a material, thickness and width of the wirings are set so that a voltage is evenly supplied to the plurality of electron emission devices 54.

[0048] The n-pieces Y-direction wirings 53 have external D_{y1}, D_{y2},......, and D_{yn}, respectively, and are formed similarly to the X-direction wirings 52.

[0049] An interlayer insulating layer (not shown) is formed between the m-pieces X-direction wirings 52 and the n-pieces Y-direction wirings 53, and the wirings are electrically isolated from each other, thus constituting the matrix wiring. Note that both of m and n are a positive integer.

[0050] The interlayer insulating layer (not shown) is SiO_2 and the like, which are formed by use of a vacuum deposition method, a printing method, a sputtering method or the like, and is formed on the entire surface of the substrate 1 or a part thereof, in which the X-direction wirings 52 are formed, so as to have a desired shape. Particularly, the film thickness, material and manufacturing method of the interlayer insulating layer are suitably set so as to be capable of withstanding a potential difference at crossing portions of the X and Y-direction wirings 52 and 53.

[0051] Moreover, the device electrodes (not shown) of the electron emission device 54, which face each other, are electrically coupled by the m-pieces X-direction wirings 52, the n-pieces Y-direction wiring s 53 and the coupling lines 55 made of a conductive metal, which are formed by use of the vacuum deposition method, the printing method, the sputtering method or the like.

[0052] Herein, the m-pieces X-direction wirings 52, the n-pieces Y-direction wirings 53, the couple lines 55, and the device electrodes facing to each other may be formed by the same material or different materials in the parts of their constituent components or the total thereof, and the materials of them are suitably selected from the foregoing ones of the device electrodes. The wirings coupled to the device electrodes are sometimes generally called a device electrode when the wirings have the same material as that of the device electrode. In addition, the electron emission device 54 may be formed either on the substrate 1 or an interlayer insulating layer (not shown).

[0053] Moreover, to be described in detail, scanning signal application means (not shown) for applying a scanning signal is coupled to the foregoing X-direction wirings 52 in order to scan the column of the electron emission device 54 arrayed in the X-direction in accordance with the input signal.

[0054] On the other hand, to modulate each column of the electron emission devices 54 arrayed in the Y-direction, modulation signal generation means (not shown) for applying a modulating signal is electrically coupled to the Y-direction wirings 53. Moreover, a driving voltage applied to each of the electron emission devices 54 is supplied as a voltage difference between the

scanning signal and the modulating signal, which are applied to the electron emission device 54.

[0055] Next, an example of an image formation apparatus using the electron source of the present invention adopting the foregoing simple matrix array will be described by use of Figs. 6 to 8. Fig. 6 is a basic constitutional view of a display panel 81, Fig. 7 is a drawing showing a fluorescent film 64, and Fig. 8 is a block diagram showing an example of a driving circuit for performing a television displaying in accordance with a TV signal of a NTSC system.

[0056] In Fig. 6, reference numeral 1 denotes a substrate of the electron source in which the electron emission devices are arrayed in the above described manner; 61, a rear plate fixing the substrate 1; 66, a face plate in which a fluorescent film 64, a metal back 65 and the like are formed on the interior surface of a glass substrate 63; and 62, a supporting frame. A casing 68 is constituted by coating flit glass or the like onto the rear plate 61, the supporting frame 62 and the face plate 66 and by baking them in the air or nitrogen gas at 400 ℃ to 500 ℃ for ten minutes or more.

[0057] In Fig. 6, reference numerals 52 and 53 are the X and Y-direction wirings coupled to the pair of device electrodes 2 and 2' of the electron emission device 54 respectively, and the X and Y-direction wirings 52 and 53 have the external terminals D_{x1} to D_{xm}, and D_{y1} to D_{yn}, respectively.

[0058] The casing 68 is constituted by the face plate 66, the supporting frame 62 and the rear plate 61, as described above. However, the rear plate 61 is principally provided with the intention for the reinforcement of the strength of the substrate 1. When the substrate 1 itself possesses sufficient strength, the rear plate 61 as a separate member is unnecessary. The supporting frame 62 may be hermetically attached to the substrate 1, thus constituting the casing 68 by the face plate 66, the supporting frame 62 and the substrate 1. Moreover, a supporting body (not shown) called a spacer is further provided between the face plate 66 and the rear plate 61, whereby the casing 68 having a sufficient strength against the air can be produced.

[0059] Although the fluorescent film 64 is formed of only fluorescent substance 72 in the case of monochrome, the fluorescent film 64 is constituted by a black conductive material 71 and a fluorescent substance 72 called a black stripe (Fig. 7(a)) or a black matrix (Fig. 7(b)) according to the array of the fluorescent substance 72 in the case of the color fluorescent film 64. The object to provide

the black stripe and the black matrix is to make color mixture and the like inconspicuous by blackening the boundary between the fluorescent substances 72 of three primaries, which are necessary for color displaying. Another object is to suppress the decrease of contrast owing to external reflection in the fluorescent film 74. As the material of the black conductive member 71, not only a material essentially containing graphite ordinarily widely used but also other materials can be used as long as the materials are conductive and show less light transmittance and reflection.

[0060] As the method to coat the fluorescent substance 72 on the glass substrate 73, a deposition method and a printing method are used irrespective of monochrome displaying and color displaying.

[0061] Furthermore, as shown in Fig. 6, the metal back 65 is ordinarily provided on the interior surface side of the fluorescent film 64. The metal back 65 is used for the purpose of enhancing luminance by mirror-reflecting light among light emitted by the fluorescent substance 72 (see Fig. 7) to the glass substrate 63 side, which is to be propagated toward the inside, of acting as an electrode for applying an electron beam acceleration voltage, and protecting the fluorescent substance 72 from damages by collisions of negative ions generated within the casing 68. The metal back 65 can be prepared in such a manner that after the preparation of the fluorescent film 64, the interior surface of the fluorescent film 64 is subjected to a smoothing treatment (usually called filming), and then Al is deposited by use of a vacuum deposition and the like.

[0062] To enhance the conductivity of the fluorescent film 64, in the face plate 66, a transparent electrode (not shown) may be provided on the outer surface side of the fluorescent film 64.

[0063] When the foregoing hermetic attachment is conducted, since the fluorescent substance 72 of each color and the electron emission device 64 must correspond to each other in the case of color displaying, it is necessary to perform full position alignment.

[0064] Inside of the casing 68 is made to be a vacuum of about 10^{-7} Torr through an air exhaustion pipe (not shown), and sealed. Furthermore, immediately before or after the casing 68 is sealed, a gettering treatment is sometimes performed. This is a treatment in which a getter (not shown) arranged at a predetermined position in the casing 68 is heated to form a deposition film. The getter usually contains Ba and the like essentially, and

serves to maintain a vacuum of, for example, 1×10^{-5} to 1×10^{-7} Torr by the absorption function of the deposition film.

[0065] The foregoing display panel 81 can be driven by, for example, a driving circuit as shown in Fig. 8. Note that in Fig. 8, reference numeral 81 denotes a display panel; 82, a scanning circuit; 83, a control circuit; 84, a shift register; 85, a line memory; 86, a synchronous signal separation circuit; 87, a modulation signal generator; and V_x and V_a, DC voltage source.

[0066] As shown in Fig. 8, the display panel 81 is electrically coupled to an external electric circuit through the external terminals D_{x1} to D_{xm}, the external terminals D_{y1} to D_{yn} and the high voltage terminal Hv. Among these external terminals, a scanning signal is applied to the external terminals D_{x1} to D_{xm}, the scanning signals being for sequentially driving an electron emission device group one column by one column (n devices by n devices), in which the electron emission devices provided in the foregoing display panel 81 are matrix-arrayed in the form of matrix of m-columns and n-rows.

[0067] On the other hand, a modulation signal is applied to the external terminals D_{y1} to D_{yn}, the modulation signal being for controlling an output electron beam of each electron emission device in one column selected by the foregoing scanning signal. Moreover, a DC voltage of, for example, 10 kV is supplied to the high voltage terminal Hv from the DV voltage source Va. This is an acceleration voltage for imparting energy to the electron beam output from the electron emission device, the energy being sufficient for the electron beam to excite the fluorescent substance.

[0068] The scanning circuit 82 comprises m switching elements therein (represented by S_1 to S_m in Fig. 8 schematically). Each of the switching elements S_1 to S_m selects one of an output voltage of the DC voltage power source V_x and 0V (ground level), and electrically coupled to the corresponding one of the external terminals D_{x1} to D_{xm} of the display panel 81. Each of the switching elements S_1 to S_m is operated based on the control signal T_{scan} output by the control circuit 83, and actually can be constituted easily by combining devices having a switching function like, for example, FETs.

[0069] The foregoing DC voltage source V_x in this example is set based on the characteristic of the foregoing electron emission device (threshold voltage) so that a driving voltage applied to an electron emission device which is not being scanned is the threshold voltage or less.

[0070] The control circuit 83 has a function to adjust operations of the sections of the circuit so that a proper displaying is carried out based on the image signal input from the outside. Based on a synchronous signal T_{sync} sent from the synchronous signal separation circuit 86 to be described below, control signals T_{scan}, T_{sft} and T_{mry} are generated for the sections of the circuit.

[0071] The synchronous signal separation circuit 86 is a circuit for separating a synchronous signal component and a luminance signal component from the television signal of the NTSC system input from the outside, and, as well known, can be constituted with the use of a frequency separation (filter) circuit. As is well known, the synchronous signal separated by the synchronous signal separation circuit 86 is composed of a vertical synchronous signal and a horizontal synchronous signal. Herein, for convenience's sake of an explanation, the synchronous signal is illustrated as T_{sync}. On the other hand, the luminance signal component of the image separated from the foregoing television signal is illustrated as a DATA signal for convenience's sake. This DATA signal is input to a shift register 84.

[0072] The shift register 84 serial/parallel-converts the foregoing DATA signal, which is serial-input thereto time-sequentially, for one line of the image, and operates based on the control signal T_{sft} sent from the foregoing control circuit 83. This control signal T_{sft} may be said alternatively as a shift clock of the shift register 84. Furthermore, the data equivalent to one line of the image (equivalent to driving data of the n electron emission devices), which has been subjected to the serial/parallel conversion, is output from the foregoing shift register 84 as n-pieces parallel signals I_{d1} to I_{dn}.

[0073] The line memory 85 is a storage device for storing data of one line of the image for a period of time required, and properly stores contents of I_{d1} to I_{dn} in accordance with the control signal T_{mry} sent from the control circuit 83. The stored contents are output as $I_{d'1}$ to $I_{d'n}$, and input to the modulation signal generator 87.

[0074] The modulation signal generator 87 is a signal source for performing a drive modulation for each of the electron emission devices properly in accordance with the corresponding one of the foregoing image data $I_{d'1}$ to $I_{d'n}$, and the output signals from the modulation signal generator 87 are applied to the electron emission devices in the display panel 81 through the terminals D_{y1} to D_{yn}.

[0075] As described above, the election emission device has a clear threshold voltage in the electron emission, and emits electrons on when a voltage exceeding the threshold voltage is applied thereto. Moreover, an emission current changed depending on the change of the application voltage to the electron emission device relative to the voltage exceeding the threshold voltage. Although the degree of the change of the emission current relative to the value of the threshold voltage and the application voltage may change by altering a material, constitution and manufacturing method of the electron emission device, the following can be derived any way.

[0076] Specifically, when the pulse-like voltage is applied to the electron emission device, the electron emission does not occur even when, for example, the voltage equal to the threshold voltage or less is applied. However, when the voltage exceeding the threshold voltage is applied, the election emission occurs. At this time, first, by changing the peak value of the voltage pulse, it is possible to control the intensity of the electron beam output. Secondly, by changing the width of the voltage pulse, it is possible to control the total amount of the charges of the electron beam output.

[0077] Accordingly, as a method of modulating the electron emission device in accordance with the input signal, enumerated are a voltage modulation method and a pulse width modulation method. When the voltage modulation method is performed, the modulation signal generator 87 generates a voltage pulse of a constant length, and a circuit adopting the voltage modulation method capable of modulating the peak value of the pulse properly in accordance with data input thereto is used. Moreover, when the pulse width modulation method is performed, the modulation signal generator 87 generates a voltage pulse of a constant peak value, a circuit adopting the pulse width modulation method capable of modulating the pulse width in accordance with data input thereto is used.

[0078] The shift register 84 and the line memory 85 may adopt a digital signal system or an analog signal system. Any kind of shift register and line memory will do as long as they can perform a serial/parallel conversion of an image signal and storing of the image signal at a predetermined speed.

[0079] When the digital signal system is employed, the output signal DATA of the synchronous signal separation circuit 86 needs to be converted a digital signal. This can be performed by providing an A/D converter in an output

section of the synchronous signal separation circuit 86.
[0080] Moreover, in association with this, the circuit provided in the modulation signal generator 87 differs a little depending on whether the output signal of the line memory 85 is a digital signal or an analog signal.
[0081] Specifically, in the case of the digital signal and the voltage modulation method, for example, a D/A conversion circuit that has been well known is used as the modulation signal generator 87, and an amplification circuit and the like may be added if necessary. In addition, in the case of the digital signal and the pulse width modulation method, the modulation signal generator 87 can be easily constituted by use of a circuit obtained by combining a high speed oscillator, a counter for counting the number of waves output by the oscillator, and a comparator for comparing an output value of the counter and an output value of the foregoing memory. Moreover, an amplifier may be added thereto if necessary, which amplifies the voltage of the modulation signal, which is output from the comparator and is modulated with respect to its pulse width, to a voltage for driving the electron emission signal.
[0082] On the other hand, in the case of the analog signal and the voltage modulation method, for example, an amplification circuit using an operational amplifier and the like, which have been well known, may be used as the modulation signal generator 87. A level shift circuit and the like may be added if necessary. Moreover, in the case of the analog signal and the pulse width modulation method, a voltage control type oscillation circuit (VCO), for example, which has been well known, may be used. An amplifier for amplifying a voltage of the modulation signal to a voltage for driving the electron emission device, if necessary.
[0083] The image forming apparatus of the present invention, which has the display panel 81 and the driving circuit as described above, can emits electrons from necessary electron emission devices by applying the voltage from the terminals D_{x1} to D_{xm} and D_{y1} to D_{yn}, and applies a high voltage to the metal back 55 or the transparent electrode (not shown) through the high voltage terminal Hv to accelerate an electron beam. The image forming apparatus can performs television displaying in accordance with a television signal of the NTSC system by excitation/light-emission caused by allowing the accelerated electron beam to collide against the fluorescent film 54.
[0084] The above described constitution is a schematic constitution necessary

for obtaining the image forming apparatus of the present invention used for the displaying and the like. Detailed portions such as materials of each member are not limited to the above, and properly selected so as to be suitable for the use of the image forming apparatus. Moreover, the NTSC system is enumerated as the input signal. However, the input signal is not limited to this in the image forming apparatus of the present invention, and other systems such as a PAL system and a SECAM system will do. Moreover, a high quality TV system from a MUSE system down will do, which adopts a TV signal composed of scanning lines of the larger number than the PAL and SECM systems and the like.

[0085] Next, an example of the electron source adopting the foregoing ladder type array and the image forming apparatus of the present invention using the electron source will be described by use of Fig. 9 and Fig. 10.

[0086] In Fig. 9, reference numeral 1 denotes a substrate; 54, electron emission devices; and 94, common wirings for coupling the electron emission devices 54, the common wirings 94 being provided by ten and having external terminals D1 to D10, respectively.

[0087] The electron emission devices 54 are arrayed in parallel in plural number on the substrate 1. This is called a device column. Then, the device column is arrayed in plural number, thus constituting the electron source.

[0088] By applying a proper driving voltage between the common wirings 94 (for example, the common wiring 94 of the external terminals D_1 and D_2) of each device column, it is possible to drive each device column independently. Specifically, a voltage exceeding the threshold voltage may be applied to a device column desired to emit an electron beam therefrom, and a voltage lower than the threshold voltage may be applied to a device column desired not to emit the electron beam. With respect to the common wirings D_2 to D_9 arrayed between the device columns, the application of such a driving voltage can be performed while treating the adjacent common wirings 94, that is, the common wirings 94 for the external terminals D_2 and D_3, D_4 and D_5, D_6 and D_7, and D_8 and D_9 as united one wiring.

[0089] Fig. 10 is a drawing showing a structure of the display panel 91 comprising the electron source of the foregoing ladder type array, which is another example of the electron source of the present invention.

[0090] In Fig. 10, reference numeral 92 denotes a grid electrode; 93, an

opening for allowing electrons to pass therethrough; D_1 to D_m, external terminals for applying voltages to respective electron emission devices; and G_1 to G_n, external terminals coupled to the grid electrode 92. The common wirings 94 between the device columns are formed on the substrate 1 as united one wiring.

[0091] In Fig. 10, the same reference numerals as those in Fig. 6 denote the same members. The display panel of Fig. 10 differs greatly from the display panel 81 using the electron source adopting the simple matrix array shown in Fig. 6 in that the grid electrode 92 is provided between the substrate 1 and the face plate 66.

[0092] The grid electrode 92 is provided between the substrate 1 and the face plate 66 as described above. The grid electrode 92 can modulate an electron beam emitted from the electron emission device 54, and has a structure that the circular opening 93 is by one provided one by one so as to correspond to each electron emission device 54 to allow the electron beam to pass through the stripe-shaped electrode provided perpendicularly to the ladder-arrayed device column.

[0093] The shape and arrangement position of the grid electrodes 92 are not limited to Fig. 10, and the openings 93 may be provided in the form of mesh in plural. The grid electrode 92 may be provided, for example, around the electron emission device 54 or near the electron emission device.

[0094] The external terminals D_1 to D_m, and G_1 to G_n are coupled to a driving circuit (not shown). A modulation signal equivalent to one line of the image is applied to the column of the grid electrodes 92 in synchronization with the sequential driving (scanning) of the device column one by one, whereby irradiation of the electron beam onto the fluorescent film 64 can be controlled and the image can be displayed one line by one line.

[0095] As described above, the image forming apparatus of the present invention can be obtained by use of the electron source of the present invention, which adopts any one of the simple matrix array and the ladder type array. The image forming apparatus suitable for display devices of television conference system, computers and the like, in addition to display devices of the foregoing television broadcasting, can be obtained. Moreover, the image forming apparatus of the present invention can be used also as an exposing apparatus incorporated in an optical printer, which is provided with a

photosensitive drum.

[0096]

[Embodiments]

[Embodiment 1] As a first embodiment of the present invention, the electron emission device shown in Fig. 1 was fabricated.

[0097] First, a Ti of a thickness of 5 nm and Pt of a thickness of 30 nm were deposited in vacuum on a quartz glass substrate by use of a metal mask, thus forming a device electrode. Next, the portion between the device electrode was locally removed by FIB, thus forming a gap having a length L of 240 nm and a width W of 100 μm.

[0098] Next, after organic Pd complex solution (prepared by diluting down CCP 4230 made by Okuno Pharmacy Co. Ltd. with butyl acetate to one third) was spin-coated, and subjected to a thermal treatment in the air at 300 ℃. Further, a thermal treatment was conducted at 180 ℃ in hydrogen air flow of 2 %, which is obtained by diluting the hydrogen air with nitrogen. In this state, fine particles having a diameter ϕ of 3 to 7 nm were formed on the surface of the device in this stage.

[0099] Subsequently, a thermal treatment was conducted for 10 minutes at 500 ℃ in ethylene air flow of 0.1 %, which is obtained by diluting the ethylene air with nitrogen. When this was observed by a scanning electron microscope, it was found that a large number of fibrous carbons extending fibrously with bending portion and having a diameter of 10 to 25 nm were formed in the gap between the electrodes. Pd fine particles and fibrous carbon were not observed on the device electrode, and the Pd fine particles were considered to be absorbed in a Pt electrode.

[0100] I_e and I_f of the electron emission device fabricated in the above described manner were measured by the measurement evaluation system shown in Fig. 3.

[0101] As a result, while I_e gradually increased, I_f once decreased rapidly, and then increased gradually. Thus, I_f reached to saturation after about 600 seconds. At this time, I_e was about 0.5 μA, and I_f was about 0.5 mA.

[0102] [Embodiment 2] The electron emission device was fabricated in the same manner as the embodiment 1 except that the gap between the device electrodes was set to 500 nm, and I_e and I_f were measured. I_e and I_f were saturated after about 400 seconds, respectively, and the values of I_e and I_f were

almost equal to those of the electron emission device of the embodiment 1.

[0103] In the observation by the scanning electron microscope, similarly to the embodiment 1, it was observed that a large number of fibrous carbons were formed in the gap. Note that the fibrous carbons were few in the center of the gap.

[0104] [Embodiment 3] In a similar manner to that of the embodiment 1, the device electrodes and the gap between the electrodes were formed, and organic Pd complex solution was coated thereon and then, baking at 300 ℃ was conducted thereon. Thereafter, a thermal treatment was conducted for 10 minutes at 180 ℃ in 0.1 % ethylene air flow diluted with nitrogen, and subsequently the device electrode and the gap coated with the organic Pd complex solution was heated to 450 ℃, thus conducting a thermal treatment for 10 minutes. The electrical characteristic of the electron emission device was almost identical to that of the embodiment 1.

[0105] [Comparison example 1] The device electrodes and the gap between the electrodes were formed according to the steps similar to those of the embodiment 1, and Pd minute particles were formed. Thereafter, the thermal treatment step in ethylene atmosphere was omitted, and I_e and I_f were measured. As a result, both of I_e and I_f were not observed.

[0106] [Comparative example 2] The electron emission device was fabricated in a similar manner to that of the embodiment 1 except that the gaps between the electrodes are set to 900 nm. When I_e and I_f were measured, both of I_e and I_f were not observed at all.

[0107] When this electron emission device was observed by a scanning electron microscope, it was found that though the fibrous carbons were formed near the end of the device electrode, the fibrous carbons do not exist in the center of the gap, and the interval between both of the carbons was large. The reason why above described phenomenon occurred is as follows. When the organic Pd solution was coated, the solution concentrated near the end of the electrode due to surface tension of the solution, and the solution is little near the center of the electrode. As a result, the Pd fine particles were not formed at the center of the gap. Accordingly, it was estimated that the fibrous carbon to be deposited at the fine particles as nucleus was hard to be deposited. Therefore, the gap between the fibrous carbons was wide, and I_e and I_f were not observed. Specifically, a current did not flow between the device electrodes, and it was

estimated that the electron emission did not occur.

[0108] [Embodiment 4] The electron source in which the electron emission devices were arrayed with the simple matrix wiring was fabricated. The procedures are shown below.

[0109] After Cr of a thickness of 5 nm and Au of a thickness of 60 nm were sequentially deposited on the cleaned soda lime glass substrate by a vacuum deposition method. Thereafter, photoresist (AZ1370: made by Hext Co. Ltd.,) was coated while rotating a spinner, and baked. Thereafter, a photomask image was exposed and developed, and a resist pattern of a lower wiring was formed. An Au/Cr deposition stacked film was subjected to wet etching, thus forming the lower wiring.

[0110] An interlayer insulating layer formed of a silicon oxide film having a thickness of 0.1 μm was formed by use of a high frequency sputtering method.

[0111] A photoresist pattern for forming contact holes on the deposited silicon oxide film was formed, and the interlayer insulating layer was etched by use of the photoresist pattern as a mask, thus forming the contact holes. The etching was conducted by a RIE (Reactive Ion Etching) method using CF_4 gas and H_2 gas.

[0112] A pattern which is to be the device electrode was formed by use of a photoresist (RD-2000N-41: made by Hitachi Chemical Co., Ltd.), and Ti of a thickness of 5 nm and Ni of a thickness of 100 nm were sequentially stacked by use of a vacuum deposition method. The photoresist pattern was dissolved by organic solvent, and the Ni/Ti stacked film was lifted off, thus forming the device electrode.

[0113] After a photoresist pattern for an upper wiring was formed on the device electrode, Ti of a thickness of 5 nm and Au of a thickness of 100 nm were sequentially stacked on the device electrode by use of a vacuum deposition method, and unnecessary portions were removed by lifting-off, thus forming the upper wiring.

[0114] A resist film was formed so as to cover the portion other than the contact hole portion, and Ti of a thickness of 5 nm and Au of a thickness of 500 nm were sequentially deposited by use of a vacuum deposition method. By removing the unnecessary portions by the lifting-off, the contact hole was buried.

[0115] Similarly to the embodiment 1, a gap was formed between the device

electrodes by FIB. Moreover, similarly to the embodiment 1, organic Pd complex solution was coated by a spinner, and baked in the air at 300 ℃, thus converting the dried organic Pd complex solution to PdO. Moreover, a thermal treatment at 180 ℃ for 10 minutes was conducted in mixed gas flow of N_2 and 2 % H_2, thus forming Pd fine particles.

[0116] Similarly to the embodiment 1, a thermal treatment at 500 ℃ for 10 minutes was conducted in 0.01 % C_2H_2 air flow, thus forming fibrous carbon. When the electron emission device of this electron source was observed by a high resolution SEM (scanning type electron microscope), no fine particles and no fibrous carbon were observed. It was estimated that the Pd fine particles on the device electrode were diffused into the electrode due to the thermal treatment.

[0117] An extraction electrode and a fluorescent plate were attached to the electron source as shown in Fig. 11, and all of the electron emission devices were scan-driven in order of time. The system of Fig. 11 will be described. In the drawing, reference numeral 111 denotes a vacuum bath, and the air is exhausted from the vacuum bath 111 to a vacuum of 5 x 10^{-5} pa or less by an air exhaustion system (not shown). Reference numeral 112 denotes a window, and reference numeral 114 denotes a device body composed of an electron emission portion (inter-electrode gap), an electrode, a wiring and the like. Reference numerals 115 and 116 denote driving wirings for X and Y-direction lines. Reference numeral 117 denotes a driver for applying pulses suitable for the foregoing wiring. Reference numeral 118 denotes an extraction electrode, which is formed in such a manner that glass, on which an ITO thin film of a transparent electrode is formed, is inserted in a frame made of aluminium, and a fluorescent substance is applied to the under plane thereof.

[0118] Rectangular pulses were applied to the electron emission device by the driver 117 so that the driving voltage was 14 V and the half-selection voltage was 7 V. The extraction electrode voltage was 5 kV.

[0119] When luminescence of the fluorescent substance due to the electron emission was observed by eyes through the window 112, it was confirmed that variations of luminance of among the devices was little in the electron source of this embodiment, and uniformity of the electron emission characteristic was high.

[0120] [Embodiment 5] An image forming member was combined with the

electron source of the embodiment 4 as shown in Fig. 6, and a display device capable of displaying image information provided from various image information sources from, for example, a TV broadcasting down was constructed. A block diagram of the display device is shown in Fig. 12.

[0121] In the drawing, reference numeral 120 denotes a display panel; 121, a driving circuit for driving the display panel 120; 122, a display controller; 123, a multiplexer; 124, a decoder; 125, an I/O interface circuit; 126, a CPU; 127, an image generation circuit; 128, 129 and 130, an image memory interface circuit; 131, an image input interface circuit; 132 and 133, a TV signal receiving circuit; and 134, an input section. (Note that as a matter of course, this display device displays an image and simultaneously reproduces voice when the display receives a signal containing both of video information and speed information like a TV signal, and descriptions for circuits concerning receiving, separation, reproduction, processing and storing of the speech information, which do not relates directly to the features of the present invention and a speaker are omitted)

[0122] Each section will be described along the flow of the image signal below.

[0123] First, the TV signal receiving circuit 133 is a circuit for receiving the TV image signal transmitted by use of a radio transmission system such as radio wave and spatial optical communication. A system of the TV signal received is not particularly limited, and various systems such as a NTSC system, a PAL system and a SECAM system will do. Moreover, a TV signal composed of a large number of scanning lines (so called a high quality TV from, for example, a MUSE system down) is a signal source suitable for utilizing the advantages of the foregoing display panel, which fits a large area and a large number of pixels. The TV signal received by the TV signal receiving circuit 133 is output to the decoder 124.

[0124] Furthermore, the image TV signal receiving circuit 132 is a circuit for receiving a TV image signal transmitted by use of a cable transmission system such as a coaxial cable and an optical fiber. A system of the TV signal received is not particularly limited like the foregoing TV signal receiving circuit 133, and also the TV signal received by this circuit is output to the decoder 124.

[0125] Furthermore, the image input interface circuit 131 is a circuit for taking in an image signal supplied from the image input apparatus such as a TV camera and an image reading scanner, and the image signal taken in is output

to the decoder 124.

[0126] Moreover, the image memory interface circuit 130 is a circuit for taking in an image signal stored in a video tape recorder (hereinafter referred to as a VTR), and the image signal taken in is output to the decoder 124.

[0127] Furthermore, the image memory interface circuit 129 is a circuit for taking in the image signal stored in a video disc, and the image signal taken in is output to the decoder 124.

[0128] Furthermore, the image memory interface circuit 128 is a circuit for taking in an image signal from an apparatus like a still image disc, which stores still image data, and the still image data taken in is output to the decoder 124.

[0129] The I/O interface circuit 125 is a circuit for coupling this display device, an external computer, a computer network, and an output apparatus such as a printer. As a matter of course, the I/O interface circuit 125 inputs/outputs the image data and characters/graphic information. In some cases, the I/O interface circuit 125 can inputs/outputs a control signal and numerical data between the outside of this display device and the CPU 126 provided in this display device.

[0130] Furthermore, the image generation circuit 127 is a circuit for generating display image data based on image data and character/graphic information input thereto from the outside through the foregoing I/O interface circuit 125 and based on image data and character/graphic information output from the CPU 156. In the inside of this circuit, circuits necessary for generating the image from a rewritable memory for storing, for example, image data and character/graphic information, a read only memory storing an image pattern corresponding to a character code, and a processor for an image processing down are incorporated.

[0131] The display image data generated by this circuit is output to the decoder 124, and can be output to an external computer network and a printer through the foregoing I/O interface circuit 125 in some cases.

[0132] Furthermore, the CPU 126 performs an operation control of this display device and operations concerning a generation, selection and edition of the display image.

[0133] For example, the CPU 126 outputs a control signal to the multiplexer 123, properly selects the image signals to be displayed on the display panel, and combines them. Furthermore, at this time, the CPU 126 generates the control

signal to a display panel controller in accordance with the image signal to be displayed, and properly controls an operation of the display device including an image display frequency, a scanning method (for example, an interlace or a non-interlace), and the number of scanning lines of one screen.

[0134] Furthermore, the CPU 126 directly outputs the image data and the character/graphic information to the foregoing image generation circuit 127, or inputs the image data and the character/graphic information by accessing the external computer and the memory through the foregoing I/O interface circuit 125.

[0135] Note that as a mater of course, the CPU 126 may have to do with operations other than these operations. For example, the CPU 126 may have directly to do with functions to generate and process information like, for example, personal computer and word processors.

[0136] Alternatively, as described above, the CPU 126 is connected to an external computer network through the I/O interface circuit 125, and may perform an operation such as a numerical computation in cooperation with external equipment.

[0137] Moreover, the input section 134 is a circuit for inputting an instruction, a program, or data to the foregoing CPU 126 through the user, and various input devices including, for example, a joy stick, a bar code reader and a voice recognition apparatus in addition to a key board and a mouse can be used as the input section 134.

[0138] Furthermore, the decoder 124 is a circuit for inversely converting various image signals, which are input from the foregoing image generation circuit 127 and the foregoing TV signal receiving circuit 133 to a three primary color signal, a luminance signal, an I signal or a Q signal. Note that as shown by the dotted lines, the decoder 124 should comprise an image memory therein. The reason why the decoder 124 comprises the image memory is to deal with a TV signal requiring the image memory in the inverse conversion. Moreover, this is because, by providing the image memory, advantages that displaying of the still image becomes easier, and advantages that image processing and edition from thinning, an interpolation, an enlargement, a reduction, and synthesis of the image can be performed easily in combination with the foregoing image generation circuit 127 and CPU 126, are created.

[0139] Furthermore, the multiplexer 123 properly selects a display image based

on the control signal input from the foregoing CPU 126. Specifically, the multiplexer 123 selects a desired image signal among the image signals that have been subjected to the inverse conversion, which are input from the decoder 124, and outputs the selected image signal to the driving circuit 121. In this case, the image signal is switched within an image displaying time to select the image signal, whereby the different images can also be displayed in different areas by dividing one screen into the plurality of areas as so called multi-screen TV.

[0140] Furthermore, the display panel controller 122 is a circuit for controlling an operation of the driving circuit 121 based on the control signal input from the foregoing CPU 126 thereto.

[0141] First, with respect to a basic operation of the display panel, a signal for controlling an operation sequence of, for example, a driving power source (not shown) of the display panel is output to the driving circuit 121.

[0142] Furthermore, with respect to the driving method of the display panel, for example, a signal for controlling, for example, an image display frequency and a scanning method (for example, an interlace or a non-interlace) is output to the driving circuit 121.

[0143] Furthermore, a control signal relating to an adjustment of the image including luminance, contrast, tone and sharpness of the display image is sometimes output to the driving circuit 121 depending on circumstances.

[0144] Furthermore, the driving circuit 121 is a circuit for generating a driving signal which is applied to the display panel 120, and the driving circuit 121 operates based on the image signal input from the foregoing multiplexer 123 and the control signal input from the foregoing display panel controller 122.

[0145] The function of each section is described in the above. It is possible to display the image information input from various image information sources on the display panel 120 in this display device with the constitution shown in Fig. 12. Specifically, after various image signals from the TV broadcasting down is subjected to the reverse conversion in the decoder 124, the image signals are properly selected in the multiplexer 123, and input to the driving circuit 123. On the other hand, the display controller 122 generates the control signal for controlling the operation of the driving circuit 121 in accordance with the image signal to be displayed. The driving circuit 121 applies the driving signal to the display panel 120 based on the foregoing image signal and the control signal.

Thus, the image is displayed in the display panel 120. A series of operations are collectively controlled by the CPU 126.

[0146] Furthermore, in this display device, the image memory built in the foregoing decoder 124, the image generation circuit 127 and the CPU 126 participate in the operations of the display device. Therefore, not only the image information selected among the plurality of image information is displayed, but also the image processing for the image information to be displayed including, for example, an enlargement, reduction, rotation, movement, edge emphasis, thinning, interpolation, color conversion, and conversion of an aspect ratio of the image, and image edition including a synthesis, an erasion, a connection, a switch, and fitting can be performed. Although the descriptions of this embodiment did not mention the following, a dedicated circuit for processing and editing voice information may be provided similarly to the foregoing image processing and image edition.

[0147] Accordingly, one unit of this display device can have functions such as a display device of a TV broadcasting, a terminal device of a TV conference, an image edition device dealing with a still picture and a moving picture, a terminal device of a computer, an OA terminal device from a word processor down, and a game machine, and has a very wide application range as industrial and consumer display devices.

[0148] Note that, Fig. 12 shows nothing but an example of the display device using the display panel having the electron emission device as the electron source, and, as a matter of course, limitations are not made to this. For example, circuits concerning unnecessary functions from the viewpoint of intended end-usage may be omitted among the constituent components of Fig. 12. Moreover, on the contrary, constituent components may be added depending on the intended end-usage. For example, when the this display device is applied to a TV telephone, a receiving/transmission circuit and the like including a TV camera, a voice microphone, an illuminator, a modem and the like should preferably added thereto.

[0149] In this display device, since the display panel using the electron emission device as the electron source above all can be easily made to be thin, the depth of the display device can be made to be small. In addition, the display panel using the electron emission device as the electron source can be easily manufactured so as to have a large screen and exhibits high luminance.

Furthermore, the display panel is excellent in a characteristic of an angle of field. Accordingly, the display device can display an impressive image exhibiting sense of reality with good visibility.

[0150] Moreover, since the electron source of the present invention shows uniform electron emission characteristic among the electron emission devices, the display device can form a high quality a formed image, exhibits a high quality, and can display an image with a high definition.

[0151]

[Effects of the Invention] As described above, according to the present invention, an electron emission device showing a good electron emission characteristic can provide with high reliability, and particularly complicated steps and effective materials are not used in fabricating the electron emission device. Accordingly, in the electron source of the present invention using the plurality of electron emission device and in the image forming apparatus, since luminance of luminous points formed by the devices are even and uniform, formation of a high quality image is possible.

[Brief Description of the Drawings]

[Figure 1] Fig. 1 is a basic constitutional view of an electron emission device of the present invention.

[Figure 2] Fig. 2 is a drawing showing an example of manufacturing steps of the electron emission device of the present invention.

[Figure 3] Fig. 3 is a drawing showing a measurement evaluation system for evaluating an electron emission characteristic of the electron emission device of the present invention.

[Figure 4] Fig. 4 is a drawing showing the electron emission characteristic of the electron emission device of the present invention.

[Figure 5] Fig. 5 is a schematic view of a simple matrix electron source of the present invention.

[Figure 6] Fig. 6 is a drawing showing an embodiment of an image forming apparatus of the present invention.

[Figure 7] Fig. 7 is a drawing showing a fluorescent film used in the image forming apparatus of the present invention.

[Figure 8] Fig. 8 is a block diagram of the embodiment of the image forming apparatus of the present invention.

[Figure 9] Fig. 9 is a schematic view of a ladder type electron source of the

present invention.

[Figure 10] Fig. 10 is a drawing showing an image forming apparatus of the present invention using the ladder type electron source.

[Figure 11] Fig. 11 is a drawing showing a measurement evaluation system of the electron source of the present invention.

[Figure 12] Fig. 12 is a block diagram of an application example of an image forming apparatus of an embodiment 4 of the present invention.

[Explanations of Reference Numerals]

1	insulating substrate
2, 2'	device electrode
3	deposit essentially containing carbon
21	metal minute particles
30	current meter
31	power source
32	current meter
33	high voltage power source
34	anode electrode
35	vacuum apparatus
36	air exhaustion pump
52	X-direction wiring
53	Y-direction wiring
54	electron emission device
55	coupling line
61	rear plate
62	supporting frame
63	glass substrate
64	fluorescent film
65	metal back
66	face plate
68	casing
71	black conductive material
72	fluorescent body
81	display panel
82	scanning circuit
83	control circuit

84	shift resister
85	line memory
86	synchronous signal separation circuit
87	modulation signal generator
92	grid electrode
93	opening
94	common wiring
111	vacuum bath
112	window
114	device body
115	X-direction driving wiring
116	Y-direction driving wiring
117	driver
118	extraction electrode
119	power source
120	display panel
121	driving circuit
122	display panel controller
123	multiplexer
124	decoder
125	I/O interface
126	CPU
127	image generation circuit
128	image memory interface
129	image memory interface
130	image input memory interface
131	image memory interface
132	TV signal receiving circuit
133	TV signal receiving circuit
135	input section
130	display panel

Fig. 1

(a)

(b)

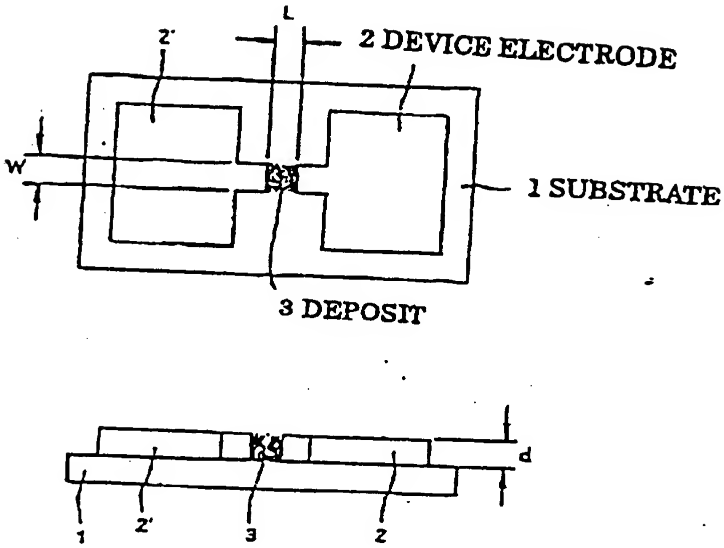


Fig. 2

(a)

(b)

(c)

(d)

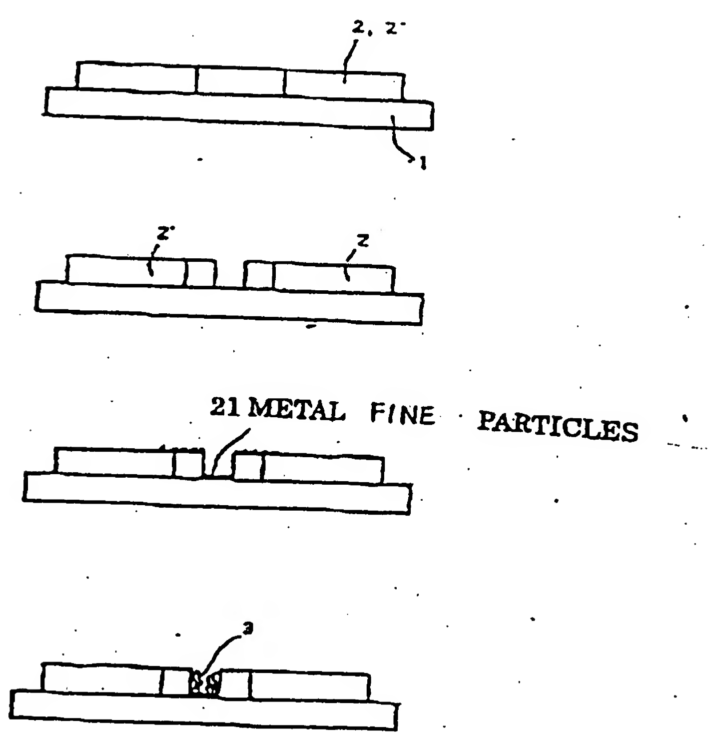


Fig.3

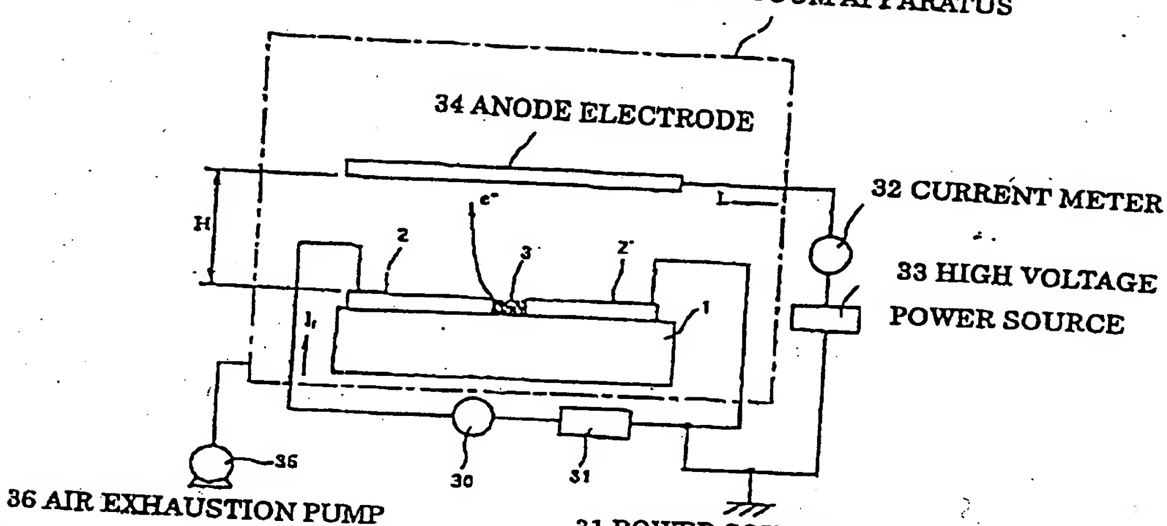

35 VACUUM APPARATUS
34 ANODE ELECTRODE
32 CURRENT METER
33 HIGH VOLTAGE
POWER SOURCE
H
2
3
2'
1
e⁻
36
30
31
36 AIR EXHAUSTION PUMP
31 POWER SOURCE
30 CURRENT METER

Fig. 4

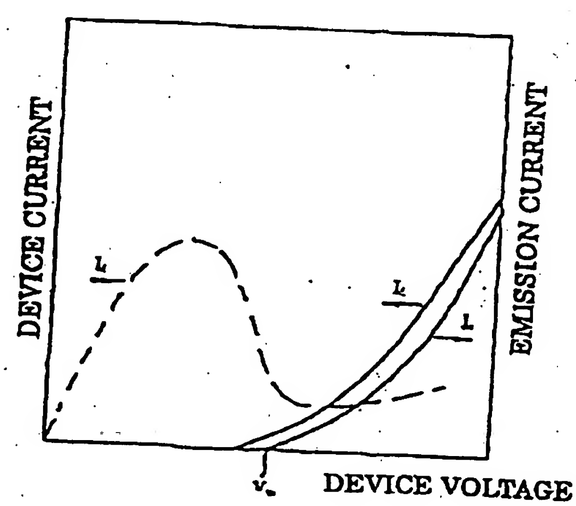

DEVICE CURRENT
EMISSION CURRENT
DEVICE VOLTAGE

Fig. 5

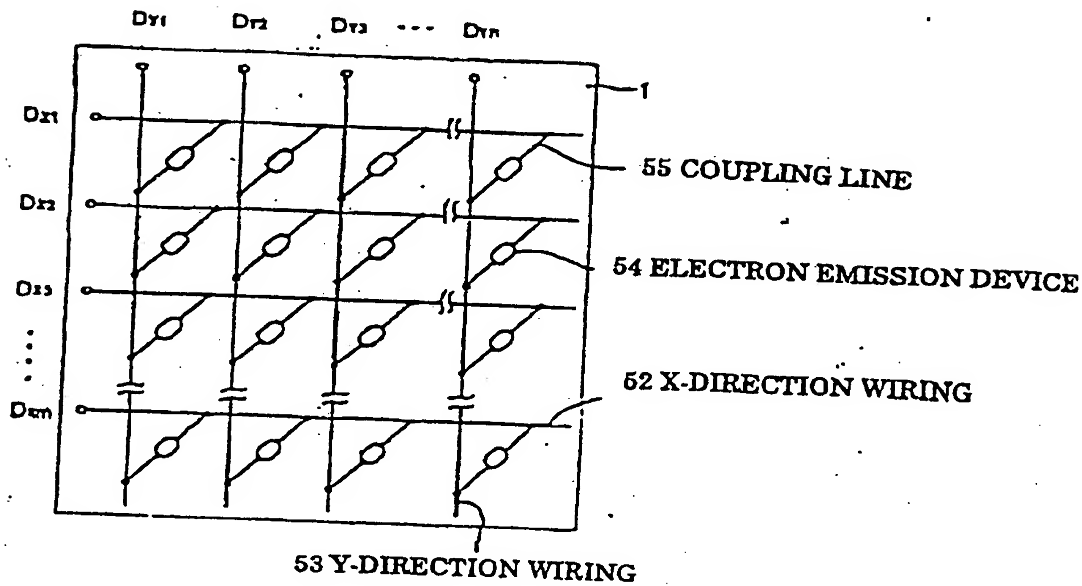
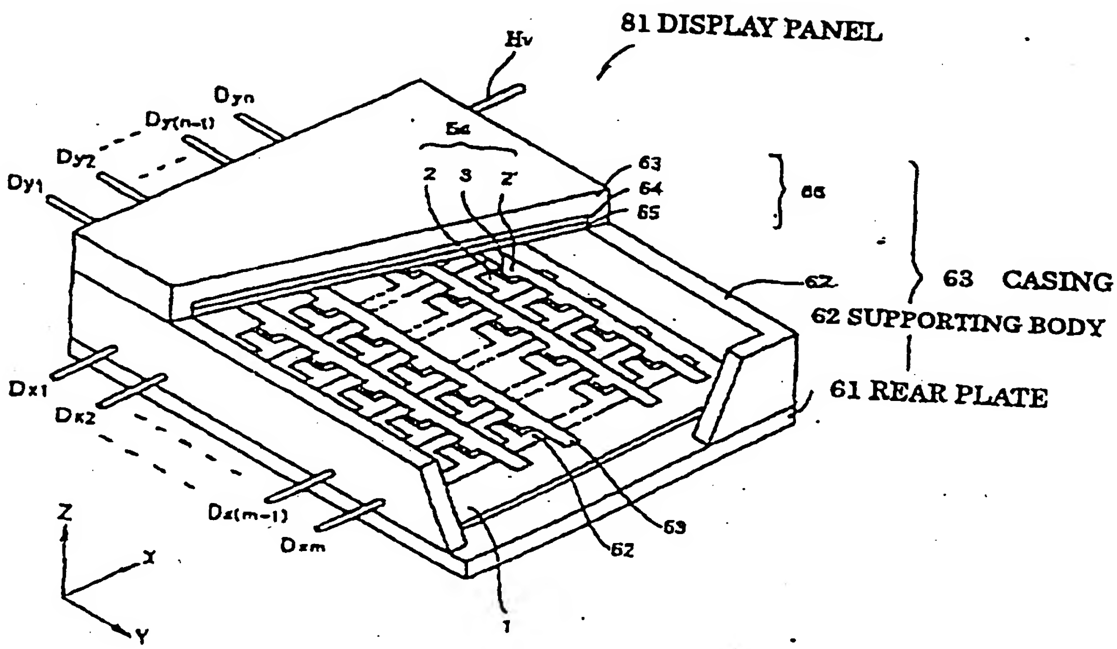

Dy1
Dy2
Dy3
Dyn
Dx1
Dx2
Dx3
Dxm
1
55 COUPLING LINE
54 ELECTRON EMISSION DEVICE
52 X-DIRECTION WIRING
53 Y-DIRECTION WIRING

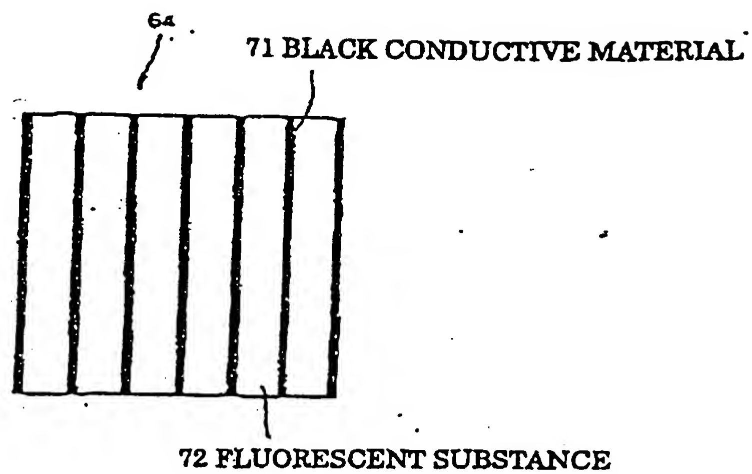
Fig. 6



63 GLASS SUBSTRATE
64 FLUORESCENT FILM
65 METAL BACK
66 FACE PLATE

Fig. 7

(a)


64
71 BLACK CONDUCTIVE MATERIAL
72 FLUORESCENT SUBSTANCE

(b)

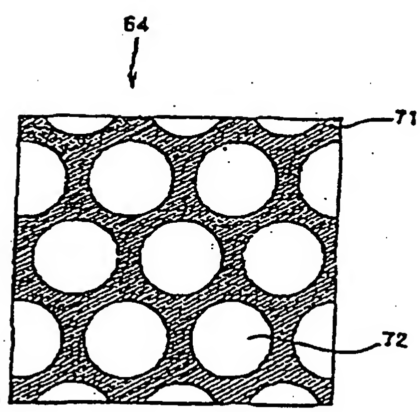

64
71
72

Fig. 8

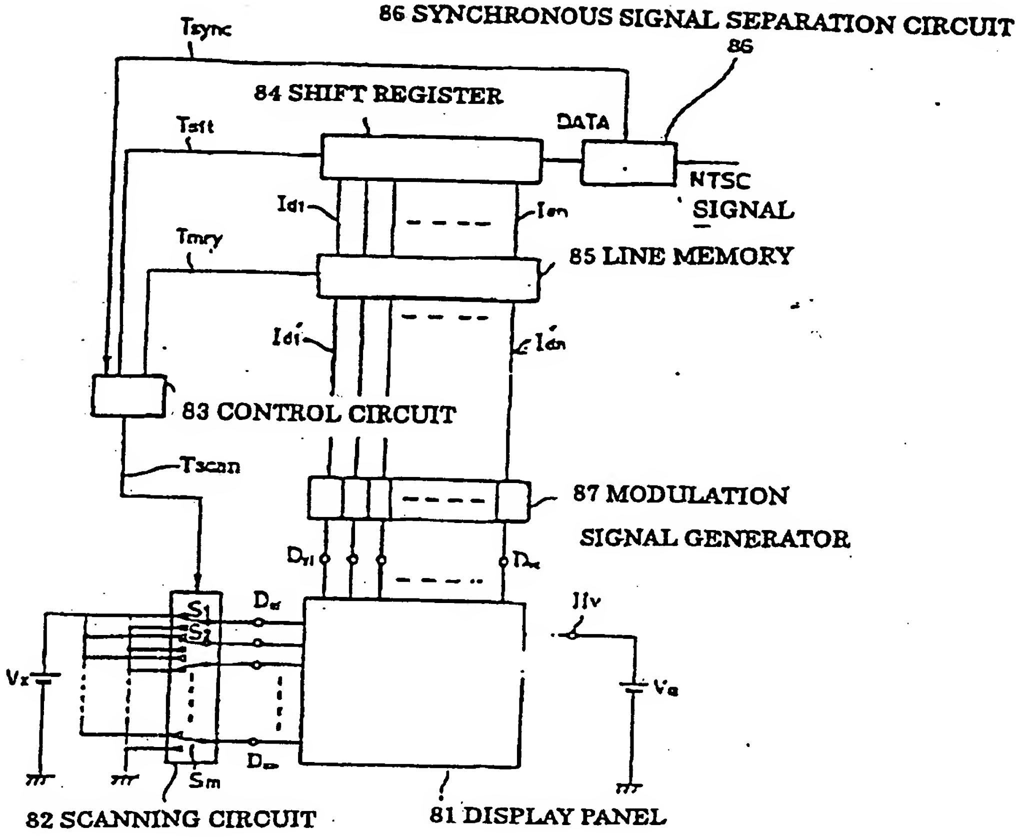
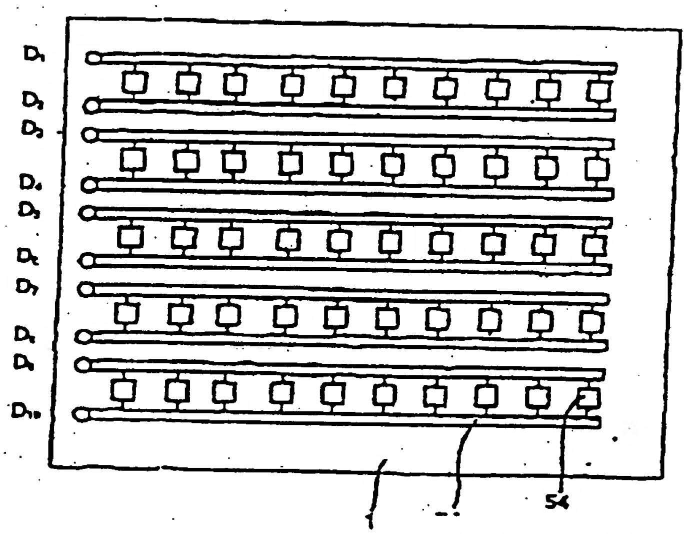
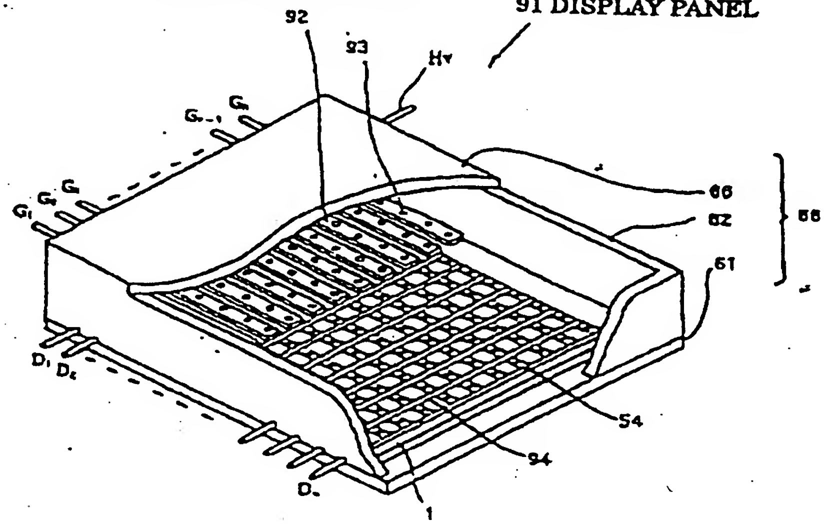

86 SYNCHRONOUS SIGNAL SEPARATION CIRCUIT
86
Tsync
84 SHIFT REGISTER
Tsft
DATA
NTSC SIGNAL
Id1
Idn
Tmry
85 LINE MEMORY
Id1'
Idn'
83 CONTROL CIRCUIT
Tscan
87 MODULATION SIGNAL GENERATOR
S1
S2
Sm
Vx
Hv
Va
82 SCANNING CIRCUIT
81 DISPLAY PANEL

Fig. 9


54
84 COMMON WIRING

Tokkaihei 08-115652

Fig.10



93 OPENING

Fig. 11

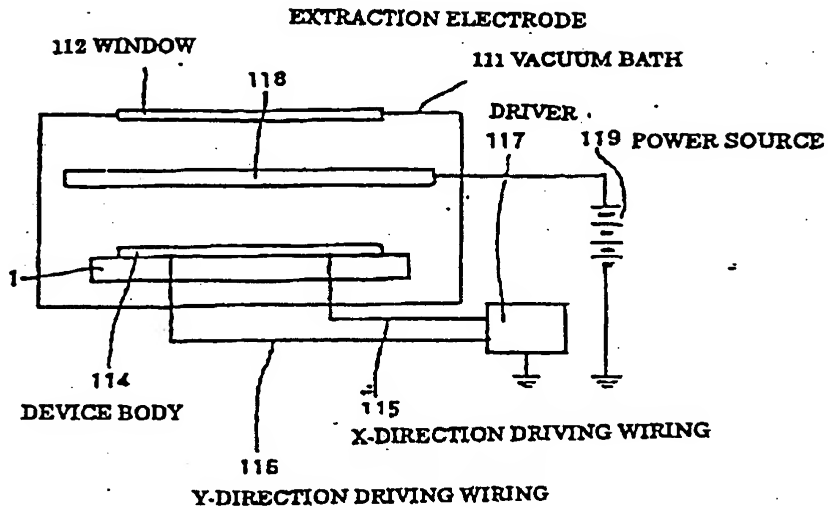
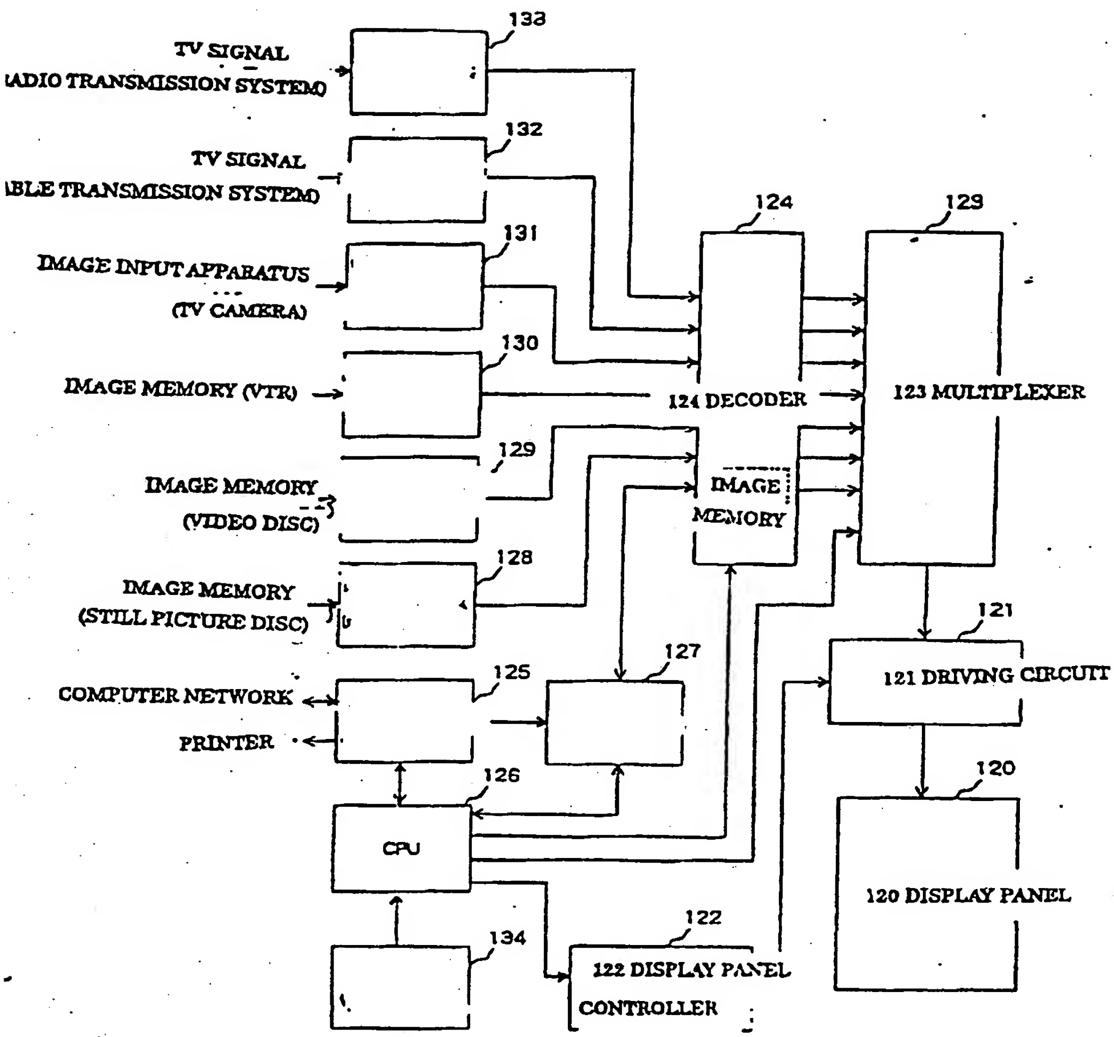

EXTRACTION ELECTRODE
112 WINDOW
118
111 VACUUM BATH
DRIVER
117
119 POWER SOURCE
1
114
DEVICE BODY
115
X-DIRECTION DRIVING WIRING
116
Y-DIRECTION DRIVING WIRING

Fig. 12



125 I/O INTERFACE CIRCUIT

127 IMAGE GENERATING CIRCUIT

128 IMAGE MEMORY INTERFACE CIRCUIT

129 IMAGE MEMORY INTERFACE CIRCUIT

130 IMAGE MEMORY INTERFACE CIRCUIT

131 IMAGE MEMORY INTERFACE CIRCUIT

132 TV SIGNAL RECEIVING CIRCUIT

133 TV SIGNAL RECEIVING CIRCUIT

134 IMPUT SECTION (KEY BOARD, MOUSE AND THE LIKE)